THE

SYNTHETIC USE OF METALS

IN

ORGANIC CHEMISTRY

BY

ARTHUR J. HALE, B.Sc.(Lond.), A.I.C.

FELLOW OF THE CHEMICAL SOCIETY; LECTURER AND DEMONSTRATOR IN CHEMISTRY AT THE CITY AND GUILDS TECHNICAL COLLEGE, FINSBURY, LONDON

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PREFACE

THE student of Organic Chemistry will probably be impressed at an early stage with the importance of metallic sodium and its compounds in synthetic work, and will subsequently mark the value of such substances as acetoacetic-, malonic-, and cyanacetic-ester and their sodium compounds.

He will notice the use of aluminium chloride in the preparation of various aromatic compounds, will hear the story of the discovery of the zinc alkyls, and will possibly be attracted by those interesting bodies, the organo-metals.

Various metals and metallic derivatives have been utilised in the development of Organic Chemistry, and during recent years, much attention has been given to the use of magnesium in the Grignard reaction and to the value of the carbides in the fixation of atmospheric nitrogen, while the reduction and synthesis of organic compounds in the presence of reduced nickel and other metals has, by development, led to the discovery of numerous catalytic changes in the presence of certain metallic oxides.

In this volume an attempt has been made to present an account of the uses to which the metals and certain of their compounds have been put, and the work is based upon a course of lectures, on this subject, recently given by the author to the advanced students of Finsbury Technical College.

Each chapter is supplemented by an appendix of practical work exemplifying the methods mentioned in the text.

Most of the preparations have been carried out in the College laboratories, and in connection with this part of the work the author desires to acknowledge the valuable assistance of two advanced students, Messrs. T. McLachlan and E. Mendoza. He is also indebted to Mr. F. W. Streatfeild, F.I.C., Senior Demonstrator, for help during the reading of the proofs.

A. J. H.

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CONTENTS.

CHAPTER I.

SODIUM AND POTASSIUM.

PAGE

Synthetic Use of the Metals—Sodium ethylate—Sodamide —Sodium hydroxide—Potassium cyanide—Potassium bisulphate—Potassium hydroxide—Potassium nitrate —Potassium and sodium disulphates 1

CHAPTER II.

COPPER AND SILVER.

Use of the Metals—Copper acetylene derivatives—Silver cyanide—Silver hydroxide 35

CHAPTER III.

MAGNESIUM, CALCIUM AND BARIUM.

Applications of the Grignard reagent—Carbides of Calcium and Barium—Nitrogen fixation—Calcium and Magnesium nitrides—Hydroxides of the metals 42

CHAPTER IV.

ZINC AND MERCURY.

Metallic Zinc—Zinc chloride—Mercuric oxide—Metallic mercury 64

CHAPTER V.

ALUMINIUM, TIN AND LEAD.

PAGE

Aluminium chloride—Aluminium-mercury couple—Tin and lead organo-metallic compounds—Tin tetrachloride—Lead oxide—Antimony and the chlorides of antimony—Vanadium pentoxide 77

CHAPTER VI.

IRON, NICKEL AND PLATINUM.

Ferrous sulphate—Ferrous potassium oxalate—Iron and ferric chloride—Reduction by reduced iron, nickel or cobalt 88

APPENDIX I.

PRACTICAL WORK: SODIUM—POTASSIUM.

Ethyl benzene—Anisole—Benzoic anhydride—Hexamethylene—Trimethylene dicarboxylic acid—Chloroformic ester—Carbonyl chloride—Ethyl benzoate—Toluic ethyl ester—Acetoacetic ester—Ethyl acetoacetic ethyl ester—Aceto-succinic ester—Malonic ester—Ethyl malonic ester—Diaceto-succinic ester—Ethane tetra-carboxylic ester—Acetyl-acetoacetic ester—Antipyrine—Methyl succinic ester—Succino-succinic ester—Tin tetraphenyl—Lead tetraphenyl—Mercury diphenyl—Silicon tetraphenyl—Oxalyl-acetic ester—Hydroxy-methylene camphor—Acetyl-acetophenone—Ethyl acetophenone—Furfurol acrolein—Cinnamyl-vinyl-methyl ketone—Acetic anhydride—Benzoin—Desyl-acetophenone—Phenanthroxylene-acetoacetic ester 104

APPENDIX II.

PRACTICAL WORK: COPPER—SILVER.

Acrolein—Acrylic acid—β-Iodopropionic acid—Adipic acid—Carbazole—o-Nitrophenyl-propiolic acid—Di-o-nitrophenyl-diacetylene—o-Chlor-toluene—o-Chlor-benzoic acid—p-Chlor-toluene—Formaldehyde 128

APPENDIX III.

PRACTICAL WORK: MAGNESIUM—CALCIUM.

PAGE

Benzoic acid—Phenyl-ethyl-carbinol—Trimethyl carbinol—Triphenyl carbinol—Camphoric anhydride—Homo-camphoric acid—Camphor—Pentamethylene—Cyanamide . 137

APPENDIX IV.

PRACTICAL WORK: ZINC—MERCURY.

Citric acid—Use of Zinc alkyl iodide—Naphthalene—Isoquinoline—Fluorescein—Malachite green—Acridine—α-Methyl-indole—Propyl chloride—α-Ethoxy-quinoline—Phthalic acid 144

APPENDIX V.

PRACTICAL WORK: ALUMINIUM—TIN—LEAD.

Dimethyl-aniline-phosphor-chloride — p-Toluic-aldehyde — Diphenyl-methane—α-Hydrindone—Triphenyl-methane—Acetophenone—o-Benzoyl-benzoic acid—Anthraquinone—Hydrolysis of anisole—Toluene—Diphenyl—Oxalic acid 153

APPENDIX VI.

PRACTICAL WORK: IRON—NICKEL.

o-Amino-benzaldehyde—o-Amino-cinnamic acid—Mannose—Hexahydrobenzene—Hexahydrophenol . . . 162

INDEX 167

ABBREVIATIONS USED IN THE BIBLIOGRAPHY.

Ann.	=	Liebig's Annalen der Chemie.
Ann. Ch. Phys.	=	Annales de Chimie et de Physique.
Ber.	=	Berichte der deutschen chemischen Gesellschaft.
Bull. Soc. chim.	=	Bulletin de la Société chimique de Paris.
Chem. Centr.	=	Chemisches Centralblatt.
Chem. Zeit.	=	Chemiker-Zeitung.
Compt. rend.	=	Comptes rendus de l'Académie des Sciences.
D.R.P.	=	German Patent.
J. Am. Chem. Soc.	=	Journal of the American Chemical Society.
J. Soc. Chem. Ind.	=	Journal of the Society of Chemical Industry.
J. prakt. Chem.	=	Journal für praktische Chemie.
Monats.	=	Monatshefte für Chemie.
Phil. Trans.	=	Philosophical Transactions.
Proc.	=	Proceedings of the Chemical Society.
Rec. Trav. Chim.	=	Recueil des travaux chimiques des Pays-Bas.
Trans.	=	Transactions of the Chemical Society.
Zeit. angew. Chem.	=	Zeitschrift für angewandte Chemie.
Zeit. phys. Chem.	=	Zeitschrift für physikalische Chemie.

THE SYNTHETIC USE OF METALS IN ORGANIC CHEMISTRY

CHAPTER I

SODIUM AND POTASSIUM

ALMOST the first metal to be used for organic synthesis, sodium continues to hold a foremost position among all the metals utilised as synthetic agents in organic chemistry. Although potassium was the first used, being applied by Frankland and Kolbe in 1848 to the preparation of hydrocarbons by heating the metal with alkyl nitriles, yet sodium has always received a far wider application. Twenty-three parts by weight of sodium suffice to bring about a chemical change which would require the use of thirty-nine parts of potassium, and this fact, together with the lower price of sodium, gives the metal an economic advantage.

Another reason for the priority of this metal is that in many cases the more electro-positive and more chemically active potassium proves to be too violent

in its action, and renders the control of the reaction difficult.

After the investigation of Frankland and Kolbe mentioned above, Frankland in the following year heated metallic zinc with alkyl iodides, and besides preparing paraffin hydrocarbons in this way, he also discovered the zinc alkyls, the first of the organo-metallic compounds.[1]

In 1850, Williamson prepared certain ethers by the interaction of alkyl iodides and sodium ethoxide, a method of preparation which rendered evident the constitution of these bodies:

$$C_2H_5I + C_2H_5ONa = NaI + C_2H_5.O.C_2H_5.$$

In 1855, Wurtz emphasised the importance of sodium for preparing the paraffin hydrocarbons, and prepared di-isobutyl, by the action of the metal upon isobutyl iodide[2]:

$$2(CH_3)_2CH.CH_2I + 2Na = (CH_3)_2CH.CH_2.CH_2.CH(CH_3)_2 + 2NaI.$$

A few years later, Fittig applied this reaction to the synthesis of aromatic hydrocarbons by condensing aryl and alkyl radicles. The following reactions will indicate the usefulness of this method[3]:

$$\underset{\text{Brombenzene.}}{C_6H_5Br} + \underset{\text{Methyl bromide.}}{CH_3Br} + 2Na = \underset{\text{Methyl benzene (toluene).}}{C_6H_5.CH_3} + 2NaBr.$$

$$\underset{\text{Dibrom-benzene.}}{C_6H_4Br_2} + \underset{\text{Ethyl iodide.}}{2C_2H_5I} + 4Na = \underset{\text{Diethyl-benzene.}}{C_6H_4(C_2H_5)_2} + 2NaI + 2NaBr$$

In these changes the alkyl groups take up the positions occupied by the halogens in the benzene nucleus.

After 1850, various compounds were prepared by

the agency of sodium and potassium, and the following are examples of some of the best known reactions of this class:

Phenol and ether formation:

$$\underset{\text{Sodium phenate.}}{C_6H_5ONa} + CH_3I = \underset{\substack{\text{Anisole}\\\text{(methyl phenyl ether).}}}{C_6H_5.O.CH_3} + NaI$$

The same exchange is effected by using an alkyl sulphate or an alkyl hydrogen sulphate:

$$C_2H_5OK + \underset{\substack{\text{Ethyl hydrogen}\\\text{sulphate.}}}{C_2H_5HSO_4} = C_2H_5.O.C_2H_5 + KHSO_4$$

$$2C_2H_5OK + \underset{\text{Methyl sulphate.}}{(CH_3)_2SO_4} = \underset{\text{Ethyl methyl ether.}}{2C_2H_5.O.CH_3} + K_2SO_4$$

The following are characteristic reactions of alkyl potassium sulphates:

When heated alone they yield olefines:

$$C_2H_5KSO_4 = C_2H_4 + KHSO_4.$$

When boiled with water they yield alcohols:

$$C_2H_5KSO_4 + H_2O = C_2H_5OH + KHSO_4.$$

When treated with KI, KCN, K_2S, KSH, they yield alkyl iodides, nitriles, thio-ethers and mercaptans respectively:

$$RKSO_4 + KI = RI + K_2SO_4$$
$$RKSO_4 + KCN = RCN + K_2SO_4$$
$$2RKSO_4 + K_2S = R.S.R + 2K_2SO_4$$
$$RKSO_4 + KSH = R.S.H. + K_2SO_4.$$

When heated with the alkali salts of organic acids, esters are obtained:

$$RKSO_4 + CH_3COOK = CH_3COOR + K_2SO_4$$
$$RKSO_4 + \underset{\text{Sodium benzoate.}}{C_6H_5COONa} = C_6H_5COOR + KNaSO_4.$$

Acid anhydrides are produced by distilling a mixture of the acid chloride with an alkali salt of the acid :

$$\underset{\text{Acetyl chloride.}}{CH_3COCl} + CH_3COONa = \underset{\text{Acetic anhydride.}}{(CH_3CO)_2O} + NaCl$$

$$\underset{\text{Benzoyl chloride.}}{C_6H_5COCl} + C_6H_5COOK = \underset{\text{Benzoic anhydride.}}{(C_6H_5CO)_2O} + KCl$$

Numerous hydrocarbons can be prepared by the action of sodium upon halogen substitution products.

In addition to those already mentioned, unsaturated hydrocarbons can be synthesised in this way :

$$\underset{\text{Allyl iodide.}}{2CH_2:CH.CH_2I} + 2Na = \underset{\text{Diallyl.}}{CH_2:CH.CH_2.CH_2.CH:CH_2} + 2NaI$$

$$\underset{\text{Vinyl bromide.}}{2CH_2:CHBr} + 2Na = \underset{\text{Divinyl.}}{CH_2:CH.CH:CH_2} + 2NaBr$$

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Sodium has played an important *rôle* in the preparation of many polymethylene hydrocarbons and their derivatives.

The first member of this series of hydrocarbons was prepared by Freund (1882), by allowing sodium to act upon trimethylene bromide[4] :

$$CH_2\begin{matrix}CH_2Br\\CH_2Br\end{matrix} + 2Na = CH_2\begin{matrix}CH_2\\CH_2\end{matrix} + 2NaBr.$$

The same method was used in 1888, for preparing methyl tetra-methylene from 1 : 4-dibrompentane[5] :

$$CH_3.CHBr.CH_2.CH_2.CH_2Br + 2Na = \begin{matrix}CH_3.CH.\ CH_2\\ |\quad\quad |\\ CH_2.CH_2\end{matrix} + 2NaBr,$$

and again in 1894 for preparing hexamethylene from the corresponding dibromide :

$$\begin{matrix}CH_2.CH_2.CH_2Br\\ |\\ CH_2.CH_2.CH_2Br\end{matrix} + 2Na = \begin{matrix}CH_2.CH_2.CH_2\\ |\quad\ |\\ CH_2.CH_2.CH_2\end{matrix} + 2NaBr.$$

Cyclohexane.

Many polymethylene carboxylic acids can be prepared by the aid of di-sodium malonate:

$$\begin{matrix}CH_2Br\\ |\\ CH_2Br\end{matrix} + Na_2C\begin{matrix}\diagup COOC_2H_5\\ \diagdown COOC_2H_5\end{matrix} = \begin{matrix}CH_2\diagdown\\ |\\ CH_2\diagup\end{matrix}C\begin{matrix}\diagup COOC_2H_5\\ \diagdown COOC_2H_5\end{matrix} + 2NaBr$$

Trimethylene dicarboxylic ester.

The condensation product when hydrolysed gives the corresponding acid and the latter on heating, passes to a monocarboxyl compound:

$$\begin{matrix}CH_2\diagdown\\ |\\ CH_2\diagup\end{matrix}C\begin{matrix}\diagup COOH\\ \diagdown COOH\end{matrix} \xrightarrow{\text{Heat}} \begin{matrix}CH_2\diagdown\\ |\\ CH_2\diagup\end{matrix}CH.COOH + CO_2.$$

Similar compounds are formed by using trimethylene dibromide and pentamethylene dibromide.[6]

Numerous acids may be prepared by the action of carbon dioxide upon aromatic halogen compounds, in the presence of sodium.

This method was first used by Kekulé in 1866 for preparing benzoic and toluic acids from brombenzene and bromtoluene:

$$C_6H_5Br + CO_2 + 2Na = C_6H_5COONa + NaBr$$

$$C_6H_4\begin{matrix}\diagup CH_3\\ \diagdown Br\end{matrix} + CO_2 + 2Na = C_6H_4\begin{matrix}\diagup CH_3\\ \diagdown COONa\end{matrix} + NaBr.$$

Magnesium is now used instead of sodium for this type of reaction (see later).

Wurtz, by the aid of chloroformic ester, prepared the corresponding esters of these acids:

$$C_6H_5Br + 2Na + ClCOOC_2H_5 = C_6H_5.COOC_2H_5 + NaCl + NaBr.$$

Uses of Aceto-acetic Ester.

This useful reagent was discovered by Geuther in 1863, who prepared it by the action of sodium upon ethyl acetate.

About the same time Frankland and Duppa, using the same reaction, discovered that the hydrogen atoms of the methylene group are replaceable by sodium and various organic radicles.

Geuther represented the substance as $CH_3.C(OH) : CH.COOC_2H_5$, that is β-hydroxycrotonic ester, but Frankland and Duppa preferred the keto formula $CH_3.CO.CH_2.COOC_2H_5$, and represented it as aceto-acetic ester.[7]

The formation of the substance may be represented thus :

$$CH_3.COOC_2H_5 + CH_3.COOC_2H_5 = CH_3.CO.CH_2.COOC_2H_5 + C_2H_5OH.$$[8]

Wislicenus had by 1877, investigated the substance and shown that other substances contained methylene groups, the hydrogen of which could be replaced by sodium.[9]

A few years later, Conrad showed that an alcoholic solution of sodium ethoxide would suffice, in place of metallic sodium or the dry ethoxide, for this type of reaction ; he applied his method in particular to the preparation of alkyl malonic esters.[10]

Not only does condensation take place between two molecules of an ester such as acetic ester, but also between an ester and a ketone. Acetyl acetone can be prepared, for example, from acetic ester and acetone :

$$CH_3.COOC_2H_5 + CH_3.CO.CH_3 = CH_3.CO.CH_2.CO.CH_3 + C_2H_5OH.$$

Propionic and butyric esters undergo the same type of condensation :

$$2CH_3.CH_2.COOC_2H_5 = CH_3.CH_2.CO.CH(CH_3).COOC_2H_5 + C_2H_5OH$$

Propio-propionic ester.

$$2C_2H_5.CH_2.COOC_2H_5 = C_2H_5.CH_2.CO.CH(C_2H_5).COOC_2H_5 + C_2H_5OH$$

Butyrobutyric ester.

In both cases the carboxyl group of one molecule of the ester attaches itself to the α-carbon atom of the other. The yields in both cases are lower than that obtained with acetic ester, which is about 25 per cent. of that calculated.

Isobutyric and isovaleric esters were found by Hantzsch[11] to follow a different course.

The compound which might be expected when using isobutyric ester could not be isolated, and was apparently reduced by the sodium present to ethoxycaprylic ester, while simultaneously some of it became hydrolysed to hydroxycaprylic acid thus:

$$2CH(CH_3)_2.COOC_2H_5 \rightarrow$$

$$(CH_3)_2CH.C(OH)(OC_2H_5).C(CH_3)_2.COOC_2H_5$$

Not isolated.

Partly reduced to $(CH_3)_2CH.CH(OC_2H_5).C(CH_3)_2.COOC_2H_5$ Ethoxycaprylic ester.

Partly hydrolysed to $(CH_3)_2CH.CH(OH).C(CH_3)_2.COOH$ Hydroxycaprylic acid.

Similar changes occurred when using isovaleric ester and are represented by the following equations:

$$2(CH_3)_2CH.CH_2.COOC_2H_5 \rightarrow$$

$$(CH_3)_2CH.CH_2.C(OH)(OC_2H_5).CH.C_3H_7.COOR$$

Not isolated.

$(CH_3)_2CH.CH_2.CH(OC_2H_5).CH.C_3H_7.COOC_2H_5$ Ethoxycapric ester.

$(CH_3)_2CH.CH_2.CH(OH).CH.C_3H_7.COOH$ Hydroxycapric acid.

Acetoacetic ester was the first of those compounds to be studied, which contain the grouping—CO—

$CH_2—CO—$, the hydrogen of the methylene group (CH_2) being replaceable, entirely or in part, by sodium. Around its constitution and principal reactions much controversy was destined to take place, and even now the last word has not been heard concerning this important and interesting substance.

Geuther, endeavouring to show that a second hydrogen atom of acetic acid could be replaced by sodium, caused the metal to act upon acetic ester. Hydrogen was evolved, sodium ethoxide was formed, and a solid sodium compound was isolated, having the composition $C_6H_9O_3Na$, which on acidifying yielded an oil capable of forming salts with bases. Geuther also proved that by the action of alkyl iodides the sodium was replaced by alkyl, and this fact was confirmed shortly after by Frankland and Duppa.

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Wislicenus next showed that the product under discussion was acetoacetic ester and that two hydrogen atoms were replaceable by sodium in two stages. He represented the reactions in the following manner, adopting the formula of Frankland:

(i) $CH_3.CO.CHNa.COOC_2H_5 + C_2H_5I = CH_3.CO.CH(C_2H_5).COOC_2H_5 + NaI$

(ii) $CH_3.CO.CNa(C_2H_5).COOC_2H_5 + C_2H_5I = CH_3.CO.C(C_2H_5)_2.COOC_2H_5 + NaI$

Geuther ascribed the enolic or hydroxylic formula $CH_3.C(OH):CH.COOC_2H_5$ to the substance, maintaining that it explained better its chemical nature.[12]

Claisen was the first to propose an important explanation of its mode of formation, and offered a view which is still regarded with favour.[13] This view is, that the condensation of acetic ester, and other con-

densations of this type, take place through the formation and subsequent decomposition of an intermediate addition compound, in the formation of which sodium ethylate plays an important *rôle*. The stages of the reaction may therefore be represented thus:

$$CH_3.COOC_2H_5 + C_2H_5ONa = CH_3.C(ONa)(OC_2H_5)_2 \text{ (Intermediate compound).}$$

$$CH_3.C(ONa)(OC_2H_5)_2 + CH_3.COOC_2H_5 =$$

$$CH_3.C(ONa):CH.COOC_2H_5 + 2C_2H_5OH.$$

Sodium derivative.

The sodium derivative is decomposed by weak acids yielding acetoacetic ester, for which reason the derivative is frequently represented with sodium linked to carbon directly and the liberation of the ester is then represented thus:

$$CH_3.CO.CHNa.COOC_2H_5 + HCl = CH_3.CO.CH_2.COOC_2H_5 + NaCl$$

The above intermediate compound has not been isolated, but by the interaction of benzoic methylester and sodium benzylate an analogous compound has been produced and separated.

$$C_6H_5.COOCH_3 + C_6H_5.CH_2ONa = C_6H_5.C(ONa)(OCH_3)(OCH_2C_6H_5)$$

Other compounds containing a methylene group, the hydrogen of which is replaceable by sodium and by alkyl groups, are:

Acetyl acetone	$CH_3CO.CH_2.COCH_3$
Malonic ester	$C_2H_5OOC.CH_2.COOC_2H_5$
Acetone dicarboxylic ester	$C_2H_5OOC.CH_2.CO.CH_2.COOC_2H_5$
Cyanacetic ester	$NC.CH_2.COOC_2H_5$
Benzyl cyanide	$NC.CH_2.C_6H_5$
Deoxybenzoin	$C_6H_5.CH_2.COC_6H_5$.

A few applications illustrating the value of these sodium derivatives may now be outlined.

The sodium derivative of acetoacetic ester, prepared by treating the ester with an alcoholic solution of sodium ethylate, is converted into an alkyl substituted ester by boiling with any alkyl iodide:

$$CH_3.CO.CH_2.COOC_2H_5 \rightarrow CH_3.CO.CHNa.COOC_2H_5 \rightarrow CH_3.CO.CHR.COOC_2H_5$$

A second radicle R^1 may be caused to replace the second hydrogen of the methylene group, by repeating the treatmont with sodium ethylate and an alkyl iodide R^1I.

$$CH_3.CO.CHR.COOC_2H_5 \rightarrow CH_3.CO.CNaR.COOC_2H_5 \rightarrow CH_3.CO.CR^1R.COOC_2H_5$$

These substituted esters, like aceto-acetic ester itself, can be hydrolysed in two different ways and thus yield a variety of ketones and acids of the acetic series.[14]

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Boiling with dilute acid or dilute alkali brings about *ketonic* hydrolysis chiefly:

$$CH_3.CO.\underset{\displaystyle R^1}{\overset{\displaystyle R}{C}}.COOC_2H_5 + H_2O = \underset{\text{Ketone}}{CH_3.CO.CHRR^1} + CO_2 + C_2H_5OH,$$

while boiling with strong alkali favours *acid* hydrolysis:

$$CH_3.CO.\underset{\displaystyle R^1}{\overset{\displaystyle R}{C}}.COOC_2H_5 + 2H_2O = CH_3COOH + \underset{\text{Acid}}{CHRR^1COOH} + C_2H_5OH.$$

Malonic ester in particular can be used for preparing higher acids of the acetic series by first

replacing one or both of the methylene hydrogens by an alkyl group :

$$CH_2\begin{matrix}COOC_2H_5\\COOC_2H_5\end{matrix} \rightarrow CHR\begin{matrix}COOC_2H_5\\COOC_2H_5\end{matrix} \text{ or } CRR^1\begin{matrix}COOC_2H_5\\COOC_2H_5\end{matrix}$$

On hydrolysis these substituted malonic esters give the corresponding acids and the latter on being heated to 200° lose carbon dioxide :

$$CHR\begin{matrix}COOH\\COOH\end{matrix} \rightarrow R.CH_2.COOH\,;\quad CRR^1\begin{matrix}COOH\\COOH\end{matrix} \rightarrow RR^1CH.COOH$$

The monosodium derivative of aceto-acetic ester on treatment with iodine undergoes condensation to a dibasic ester (diaceto-succinic ester).

$$\begin{matrix}CH_3.CO.CHNa.COOC_2H_5\\CH_3.CO.CHNa.COOC_2H_5\end{matrix} + I_2 = \begin{matrix}CH_3.CO.CH.COOC_2H_5\\|\\CH_3.CO.CH.COOC_2H_5\end{matrix} + 2NaI$$

The mono-sodium compound of malonic ester gives a tetra-carboxylic ester when similarly treated (ethane tetra-carboxylic ester):

$$2CHNa\begin{matrix}COOC_2H_5\\COOC_2H_5\end{matrix} + I_2 = \begin{matrix}CH(COOC_2H_5)_2\\|\\CH(COOC_2H_5)_2\end{matrix} + 2NaI$$

Acetyl aceto-acetic ester is prepared by the action of acetyl chloride upon the compound $CH_3.CO.CH\,Na.COOC_2H_5$, and on hydrolysis gives acetic and aceto-acetic acids :

$$\begin{matrix}CH_3.CO.CH.COOC_2H_5\\|\\COCH_3\end{matrix} + 2H_2O =$$
$$CH_3.COOH + CH_3.CO.CH_2.COOH + C_2H_5OH$$

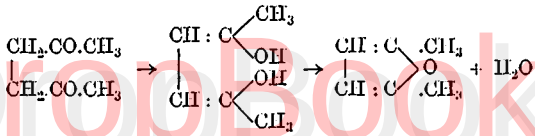
In a similar manner, by using α-monochloracetone, the γ-diketone, acetonyl acetone, is obtained after hydrolysis[15]:

$$CH_3.CO.CHNa.COOC_2H_5 + ClCH_2.CO.CH_3 = CH_3.CO.CH(CH_2.COCH_3).COOC_2H_5 + NaCl$$

Heating with water at 160° is sufficient to hydrolyse the substitution compound and eliminate carbon dioxide :

$$CH_3.CO.CH(CH_2.CO.CH_3).COOC_2H_5 \rightarrow CH_3.CO.CH(CH_2.CO.CH_3).COOH \rightarrow CH_3.CO.CH_2.CH_2.CO.CH_3 + CO_2$$

Acetonyl acetone affords a means of passing to furfurane, thiophene, and pyrrol derivatives. Heated with dehydrating agents such as zinc chloride or phosphorus pentoxide, it yields dimethyl furfurane, a change which is sometimes explained by the following steps:



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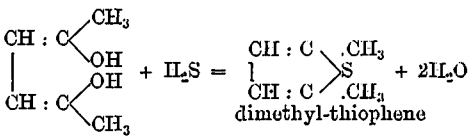
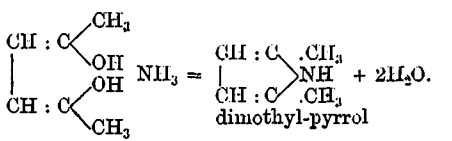
Heated with phosphorus pentasulphide it yields the corresponding thiophene compound, while the action of alcoholic ammonia solution forms a pyrrol compound :



dimethyl-thiophene



dimethyl-pyrrol

The behaviour of sodium ethyl aceto-acetate towards chloracetic ester and chloroformic ester respectively, indicates that the compound exhibits *dynamic isomerism* because in the first reaction it behaves as though sodium were directly united to carbon, and in the second reaction as though the sodium were united to oxygen :

$$CH_3.CO.CHNa.COOC_2H_5 + ClCH_2.COOC_2H_5 = CH_3.CO.\underset{\displaystyle CH_2.COOC_2H_5}{\underset{|}{C}}H.COOC_2H_5$$

Aceto-succinic ester

$$CH_3.CONa : CH.COOC_2H_5 + ClCOOC_2H_5 = CH_3.C\begin{matrix} \diagup\, OCOOC_2H_5 \\ \diagdown\!\!\diagdown\, CH.COOC_2H_5 \end{matrix}$$

β-carbethoxy-crotonic ester

From acetyl-acetone a series of β- or 1 : 3-diketones can be obtained by treating the mono-sodium compound with alkyl iodides :

$$CH_3.CO.CHNa.CO.CH_3 + C_2H_5I = CH_3.CO.CH(C_2H_5).CO.CH_3 + NaI$$

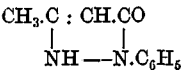
Treatment of the sodium derivative with iodine gives tetra-acetyl ethane :

$$\begin{matrix} CH_3.CO.CHNa.CO.CH_3 \\ | \\ CH_3.CO.CHNa.CO.CH_3 \end{matrix} + I_2 = \begin{matrix} CH_3.CO.CH.CO.CH_3 \\ | \\ CH_3.CO.CH.CO.CH_3 \end{matrix} + 2NaI$$

Aceto-acetic ester is technically valuable in the preparation of antipyrine. The ester is first allowed to react with phenyl-hydrazine, and the ring compound formed is then converted into antipyrin by methyl iodide and sodium :

$$CH_3.CO.CH_2.COOC_2H_5 + C_6H_5.NH.NH_2 = \begin{matrix} CH_3.C.CH_2.COOC_2H_5 \\ \| \\ N.NH.C_6H_5 \end{matrix} + H_2O.$$

The hydrazone then loses C_2H_5OH and forms 1-phenyl-3-methyl pyrazolon :



which then passes to 1 : 2 : 3-phenyl dimethyl-pyrazolon.

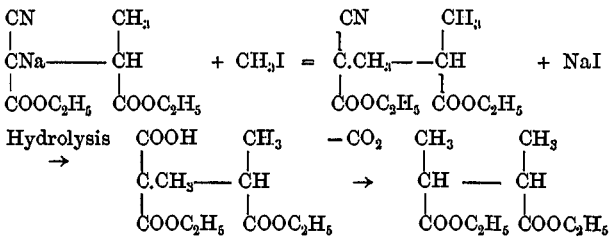
From benzylcyanide and deoxybenzoin alkyl derivatives can be formed by the action of sodium and alkyl halides :

$$C_6H_5.CH_2.CN \rightarrow C_6H_5.CHR.CN$$
$$C_6H_5.CH_2.COC_6H_5 \rightarrow C_6H_5.CHR.COC_6H_5$$

The preparation of dimethyl succinic ester will illustrate the use of cyanacetic ester.[16]

The sodium compound is condensed with α-bromopropionic ester to form cyano-methyl succinic ester :

This substance is then treated with NaOEt and CH_3I and the product hydrolysed with loss of carbon dioxide :



The synthesis of δ-keto-hexahydrobenzoic acid further illustrates the use of cyanacetic ester.[17]

The di-sodium derivative is condensed with β-iodo-propionic ester to form γ-cyanopentane-αγε-tricarboxylic ester:

$$C_2H_5OOC.C(CN)Na_2 + 2CH_2I.CH_2.COOC_2H_5 = C_2H_5OOC.C(CN)\begin{cases}CH_2.CH_2.COOC_2H_5\\CH_2.CH_2.COOC_2H_5\end{cases} + 2NaI$$

Hydrolysis of this cyano-ester gives pentane-αγε-tricarboxylic acid, which on digestion with acetic anhydride and subsequent distillation yields δ-keto-hexahydro-benzoic acid:

$$HOOC.CH\begin{cases}CH_2.CH_2.COOH\\CH_2.CH_2.COOH\end{cases} = HOOC.CH\begin{cases}CH_2.CH_2\\CH_2.CH_2\end{cases}CO + CO_2 + H_2O.$$

Further examples of the synthesis of cyclic compounds are:

The formation of butane tetra-carboxylic ester from ethylene dibromide and mono-sodium-malonic ester:

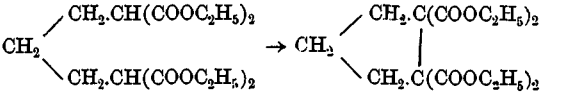
$$\begin{matrix}CH_2Br\\|\\CH_2Br\end{matrix} + \begin{matrix}CH(Na)(COOC_2H_5)_2\\\\CH(Na)(COOC_2H_5)_2\end{matrix} = \begin{matrix}CH_2.CH(COOC_2H_5)_2\\|\\CH_2.CH(COOC_2H_5)_2\end{matrix} + 2NaBr$$

When the sodium derivative of butane tetra-carboxylic ester is acted upon by bromine, the resulting product is tetramethylene-1 : 2-tetracarboxylic ester:

$$\begin{matrix}CH_2.CNa(COOC_2H_5)_2\\|\\CH_2.CNa(COOC_2H_5)_2\end{matrix} + Br_2 = \begin{matrix}CH_2.C(COOC_2H_5)_2\\|\\CH_2.C(COOC_2H_5)_2\end{matrix} + 2NaBr.$$

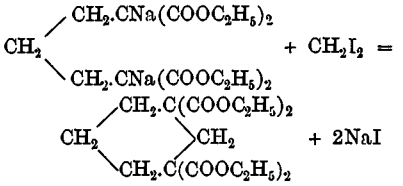
The use of trimethylene bromide with sodium

malonic ester will make the following reactions possible:

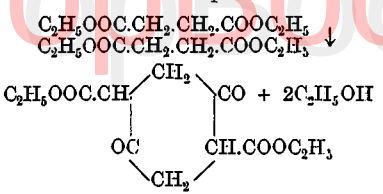


Pentamethylene-tetracarboxylic ester

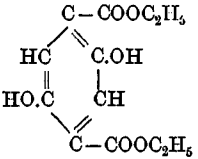
Using methylene iodide instead of bromine, a cyclohexane-tetracarboxylic ester results:



Succino-succinic ester is formed by the condensation of succinic ester in the presence of sodium:[18]



and this on oxidation is converted into 2 : 5-dihydroxy-terephthalic ester:



Succino-succinic ester can also be prepared by the action of sodium upon α-bromaceto-acetic ester.[19]

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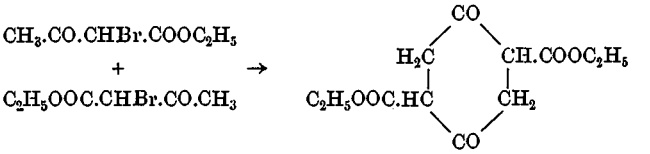
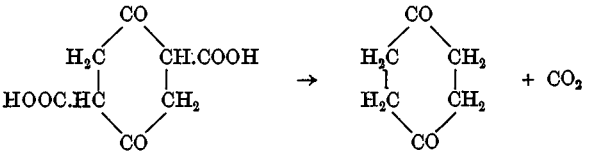


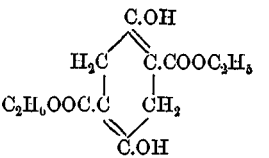
When hydrolysed with sodium hydroxide the ester passes to the corresponding acid, and this is decomposed when heated to 200° into *p*-diketohexamethylene and carbon dioxide:



The latter substance was used by Baeyer in preparing dihydro-, tetrahydro-, and hexahydrobenzene.[20]

Succino-succinic ester was also used by Baeyer for synthesising the terpene hydrocarbon *p*-menthadiene.[21]

Succino-succinic ester, like phloroglucin, exhibits dynamic isomerism (tautomerism), behaving under some conditions as a keto-body, and under other conditions as a hydroxylic, or phenolic body having this structure:



A further example of ester and ketone condensa-

tion is afforded by the synthesis of acetyl-pyroracemic ester, from acetone and oxalic ester:

$$CH_3.CO.CH_3 + \begin{matrix}COOC_2H_5\\ |\\ COOC_2H_5\end{matrix} = CH_3.CO.CH_2.CO.COOC_2H_5 + C_2H_5OH$$

By using mesityl oxide and oxalic ester the condensation product is mesityl-oxide-oxalic ester:

$$\begin{matrix}CH_3\\ \\ CH_3\end{matrix}\!\!>\!C:CH.CO.CH_3 + \begin{matrix}COOC_2H_5\\ |\\ COOC_2H_5\end{matrix} =$$

$$\begin{matrix}CH_3\\ |\\ C\\ |\\ CH_3\end{matrix}\!\!:CH.CO.CH_2.CO.COOC_2H_5 + C_2H_5OH$$

A case of internal condensation similar to that of succinic ester, is the formation of keto-pentamethylene carboxylic ester from 1 : 4-butane dicarboxylic ester:

$$\begin{matrix}CH_2-CH_2COOC_2H_5\\ |\\ CH_2-CH_2COOC_2H_5\end{matrix} = \begin{matrix}CH_2-CH.COOC_2H_5\\ |\quad\quad\quad\\ CH_2-CH_2\end{matrix}\!\!>\!CO + C_2H_5OH$$

Sometimes condensation products are formed by the elimination of water. For example:

$$\underset{\text{Benzaldehyde}}{C_6H_5.CHO} + \underset{\text{Acetic ester}}{CH_3.COOC_2H_5} = \underset{\text{Cinnamic ester}}{C_6H_5.CH:CH.COOC_2H_5} + H_2O$$

$$C_6H_5.CHO + \begin{matrix}CN\\ \\ CH_2\\ \\ COOC_2H_5\end{matrix} = C_6H_5CH:C\!\!<\!\!\begin{matrix}CN\\ \\ COOC_2H_5\end{matrix} + H_2O$$

Cyanacetic ester — Benzylidene cyanacetic ester

Sodium has been widely used in the synthesis of various organo-metals and organo-metalloids, by causing the halides of the elements to react with organic halogen compounds. The following are examples of this type of reaction:[22]

$$SnCl_4 + 4C_6H_5Br + 8Na = Sn(C_6H_5)_4 + 4NaBr + 4NaCl$$
$$SiCl_4 + 4C_6H_5Br + 8Na = Si(C_6H_5)_4 + 4NaBr + 4NaCl.$$

Sometimes the sodium alloy of the metal is utilised, as in the preparation of tin, lead, and mercury compounds, by means of tin-sodium, lead-sodium, and sodium amalgam respectively :[23]

$$Pb + 4Na + 4C_3H_7I = Pb(C_3H_7)_4 + 4NaI$$
$$Sn + 4Na + 4C_6H_5Br = Sn(C_6H_5)_4 + 4NaBr$$

It is advisable to accelerate these reactions by means of a small quantity of acetic ester.

Sodium Ethylate.

The value of this sodium derivative was first extensively illustrated by Claisen.[24]

It may be used for condensing esters and ketones, and esters by themselves as well as with aldehydes, in much the same manner as sodium itself.

Benzoic ester and acetone yield benzoyl-acetone.

$$C_6H_5.COOC_2H_5 + CH_3.CO.CH_3 = C_6H_5.CO.CH_2.CO.CH_3 + C_2H_5OH$$

Succinic ester and acetone yield teraconic ester.

$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>\!CO + \begin{matrix} CH_2.COOC_2H_5 \\ | \\ CH_2.COOC_2H_5 \end{matrix} = \begin{matrix} (CH_3)_2C:C.COOC_2H_5 \\ | \\ CH_2.COOC_2H_5 \end{matrix} + H_2O$$

Benzoic ester with acetic ester yields benzoyl-acetic ester, while with acetophenone it gives dibenzoyl-methane :

$$C_6H_5.COOC_2H_5 + CH_2.COOC_2H_5 = C_6H_5.CO.CH_2.COOC_2H_5 + C_2H_5OH$$
$$C_6H_5.COOC_2H_5 + CH_3.CO.C_6H_5 = C_6H_5.CO.CH_2.CO.C_6H_5 + C_2H_5OH.$$

By condensing formic ester with other monocarboxylic esters, aldehyde esters result, while by using oxalic ester, ketonic dibasic esters are formed :

$$HCOOC_2H_5 + CH_3.COOC_2H_5 = HCO.CH_2.COOC_2H_5 + C_2H_5OH$$

Formyl acetic ester.

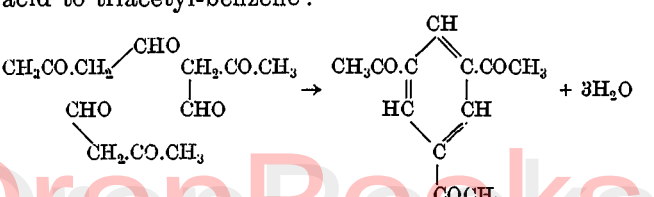
$$\begin{matrix} COOC_2H_5 \\ | \\ COOC_2H_5 \end{matrix} + \begin{matrix} CH_3COOC_2H_5 \\ \\ CH_3COOC_2H_5 \end{matrix} = \begin{matrix} CO.CH_2.COOC_2H_5 \\ | \\ CO.CH_2.COOC_2H_5 \end{matrix} + 2C_2H_5OH$$

Diacetyl dicarboxylic ester.

Formyl acetone may be prepared by using fornic ester and acetone:

$$HCOOC_2H_5 + CH_3.CO.CH_3 = HCO.CH_2.CO.CH_3 + C_2H_5OH$$

This substance can be further condensed by acetic acid to triacetyl-benzene:



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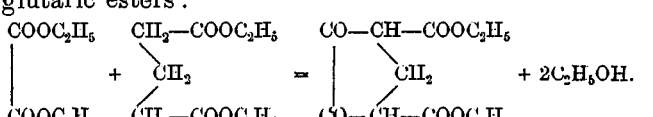
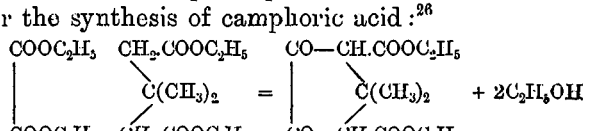
Similarly acetophenone and fornic ester yield formyl-acetophenone, which may be condensed further to tribenzoyl benzone.

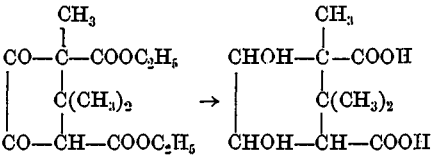
Ring condensations with oxalic ester are: Diketo-cyclopentane dicarboxylic ester from oxalic and glutaric esters:[25]



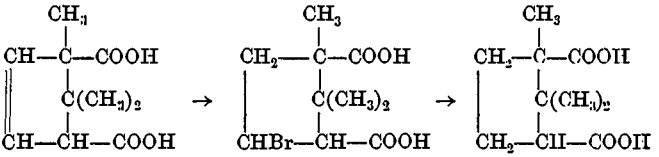
By using $\beta\beta$-dimethyl glutaric ester, Komnpa obtained diketo-apocamphoric ester which was used for the synthesis of camphoric acid:[26]



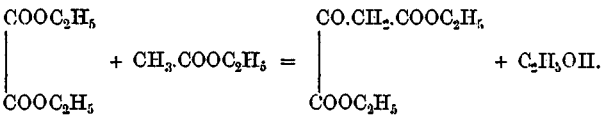
A methyl group was introduced into the latter compound by the aid of sodium and methyl iodide, and the resultant compound reduced and then hydrolysed to dihydroxy-camphoric acid:



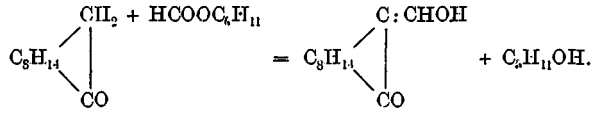
On boiling the last product with phosphorus and hydrogen iodide, the result was dehydrocamphoric acid, which was then combined with hydrogen bromide to form β-brom-camphoric acid. The last named substance was reduced by zinc dust and acetic acid to racemic camphoric acid:



Sometimes the oxalic ester only undergoes half-condensation as in the formation of oxalyl acetic ester:



By means of sodium ethylate or sodium, Claisen prepared hydroxymethylene camphor by condensing camphor with amyl formate:[27]



This substance is strongly acid, forming salts and esters, in which the hydroxyl hydrogen is replaced by metals and by organic radicles respectively. The reaction led to the discovery of many other hydroxymethylene bodies possessing similar properties.

Claisen also obtained nitroso-ketones by the use of amyl nitrite in the presence of sodium ethylate:

$$C_6H_5.CO.CH_3 + C_5H_{11}.O.NO = C_6H_5.CO.CH:NOH + C_5H_{11}OH$$

An example of this class of condensation with elimination of water is the formation of α-phenylcinnamic nitrile, from benzaldehyde and benzyl nitrile:

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Sodamide as a Synthetic Agent.

This substance was utilised by Claisen in 1905, for alkylating ketones and for preparing 1 : 3-diketones. Its action seems to be quieter and more regular than that of sodium or sodium ethylate.[28]

One or two ethyl groups may be introduced into acetophenone by using ethyl iodide with sodamide:

$$C_6H_5.CO.CH_3 + C_2H_5I = C_6H_5.CO.CH_2.C_2H_5 + HI$$
$$C_6H_5.CO.CH_3 + 2C_2H_5I = C_6H_5.CO.CH(C_2H_5)_2 + 2HI.$$

By using benzyl chloride the benzyl group can be introduced:

$$C_6H_5.CO.CH_3 + C_6H_5.CH_2Cl = C_6H_5.CO.CH_2.(CH_2C_6H_5) + HCl.$$

1 : 3-Diketones are prepared by condensing ketones with esters.

Acetyl acetone from acetic ester and acetone :

$$CH_3.COOC_2H_5 + CH_3.CO.CH_3 = CH_3.CO.CH_2.CO.CH_3 + C_2H_5OH.$$

Benzoyl acetone from acetic ester and acetophenone :

$$CH_3.COOC_2H_5 + CH_3.CO.C_6H_5 = CH_3.CO.CH_2.CO.C_6H_5 + C_2H_5OH.$$

The powdered sodamide is added gradually to the mixed substances, cooled in ice, and after standing for some time, the mixture is treated with ice-cold water and the product precipitated by acidifying with acetic acid.

Hydroxymethylene ketones are formed by using formic ester :

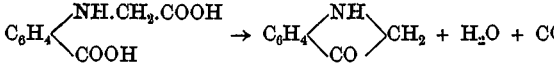
$$CH_3.CO.CH_3 + HCOOR = CH_3.CO.CH : CHOH + ROH.$$

Sodamide has been technically applied in at least two instances, namely, the production of cyanide by Castner's process and also the production of indigo.

In the preparation of cyanide, the sodamide is mixed with carbon and the mixture subjected to a dull red heat, when the following reaction takes place :

$$NaNH_2 + C = NaCN + H_2$$

Indigo can be synthesised according to the German Patent 158,089, by heating sodamide with the diethyl ester, or the diamido-derivative, of phenyl-glycocoll-carbonic acid, in benzene solution :



Indoxyl

The indoxyl formed is converted into indigo by exposure to air.

Metallic sodium has recently received important application as a polymerising agent in the transformation of isoprene into artificial rubber.[29]

The steps in this important synthesis, starting from starch, are as follows :

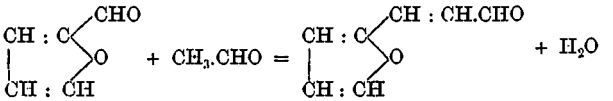
The starch is fermented to fusel oil and acetone, and from the former liquid, isoamyl alcohol is separated.

By treatment with hydrogen chloride, isoamyl alcohol is converted to the monochloride, and the vapour of this when acted upon by chlorine gas leads to the formation of three isoamyl dichlorides :

$$(CH_3)_2CH.CH_2.CH_2OH + HCl = (CH_3)_2CH.CH_2.CH_2Cl + H_2O$$

$$(CH_3)_2CH.CH_2.CH_2Cl + Cl_2 \rightarrow \begin{cases} (CH_3)_2CH.CHCl.CH_2Cl + HCl \\ (CH_3)_2CCl.CH_2.CH_3Cl + HCl \\ CH_3 \\ \quad\quad\quad\

per cent. aqueous solution, for condensing together furfurol and acetaldehyde :



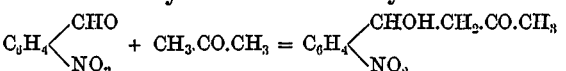
Furfurol acrolein.

Claisen, in the following year, used 10 per cent. aqueous sodium hydroxide to condense furfurol with acetone and thus obtained mono-furfurylidene acetone :[31]

$$C_4H_3O.CHO + CH_3.CO.CH_3 = C_4H_3O.CH : CH.CO.CH_3 + H_2O.$$

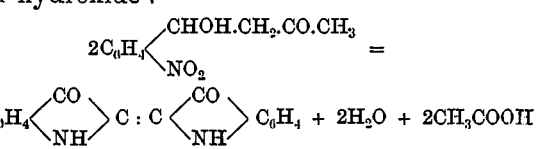
Using benzaldehyde and acetone, he obtained mono- and di-benzylidene acetone.

Further examples of condensation of this class are the formation of indigo from o-nitrobenzaldehyde and acetone, and the formation of quinoline from o-aminobenzaldehyde and acetaldehyde :



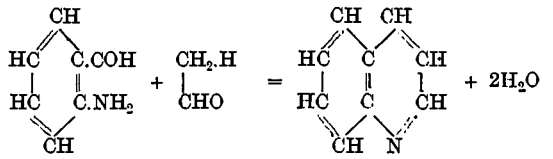
o-nitrophenyl-lactic acid ketone.

This product is then decomposed by the excess of sodium hydroxide :



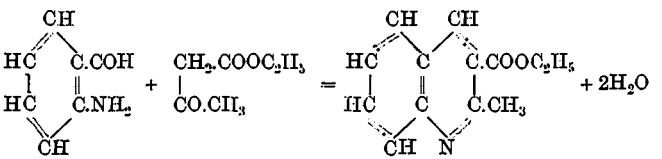
Baryta or ammonium hydroxide may also be used for this reaction.[32]

Quinoline and quinoline derivatives are obtained by using o-amino-benzaldehyde :[33]



o-amino-benzaldehyde. quinoline.

By substituting aceto-acetic ester for acetaldehyde, a quinoline derivative is obtained :



α-methyl-quinoline-*β*-carboxylic ester.

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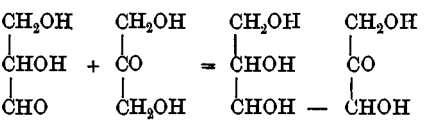
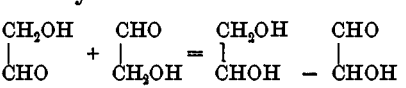
Fischer made use of 1 per cent. sodium hydroxide solution to polymerise a mixture of glyceric aldehyde and hydroxy-acetone, in the formation of *α*-acrose. After allowing the mixture to stand for four or five days the transformation was complete :[34]



(Glycerose). *α*-acrose (inactive fructose).

By the same method, glycollic aldehyde has been polymerised to erythrose :



Cinnamic aldehyde can be formed from benzal-

dehyde and acetaldehyde, and the product can be again condensed with acetaldehyde or acetone:

$$C_6H_5.CHO + CH_3.CHO = C_6H_5.CH:CH.CHO + H_2O$$

$$C_6H_5.CH:CH.CHO + CH_3.CHO = C_6H_5.CH:CH.CH:CH.CHO + H_2O$$

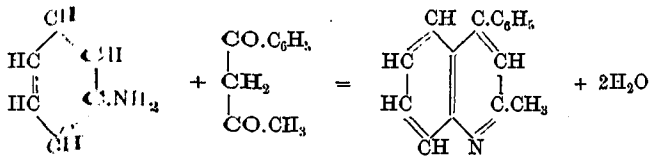
Cinnamyl acrolein.

$$C_6H_5.CH:CH.CHO + CH_3.CO.CH_3 = C_6H_5.CH:CH.CH:CH.CO.CH_3 + H_2O$$

Cinnamyl-vinyl-methyl ketone.

If two molecular quantities of cinnamic aldehyde be used, then in the last case di-cinnamyl-vinyl ketone results.

Another case of quinoline formation is the condensation of benzoyl acetone and aniline, resulting in γ-phenyl-quinaldine:

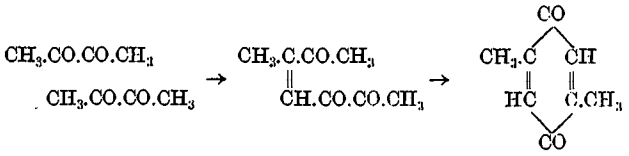


It was shown by V. Meyer, that solid sodium hydroxide is better than sodium ethylate for condensing benzyl nitrile with methyl iodide:[35]

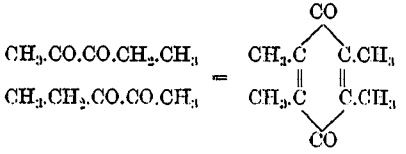
$$C_6H_5.CH_2CN + CH_3I + NaOH = C_6H_5.\underset{\displaystyle CH_3}{\underset{|}{C}}HCN + NaI + H_2O.$$

Quinones can be prepared by condensing 1:2-diketones by aqueous sodium hydroxide.[36]

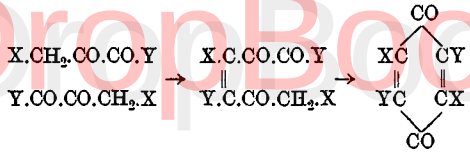
In the first place an unsaturated 1:2:5-triketone is formed which by further condensation passes to a quinone. Diacetyl gives first dimethyl-quinogen and then *p*-xyloquinone:



Acetyl-propionyl condenses in this way, forming duroquinone :



The reaction may be expressed in a general way thus :



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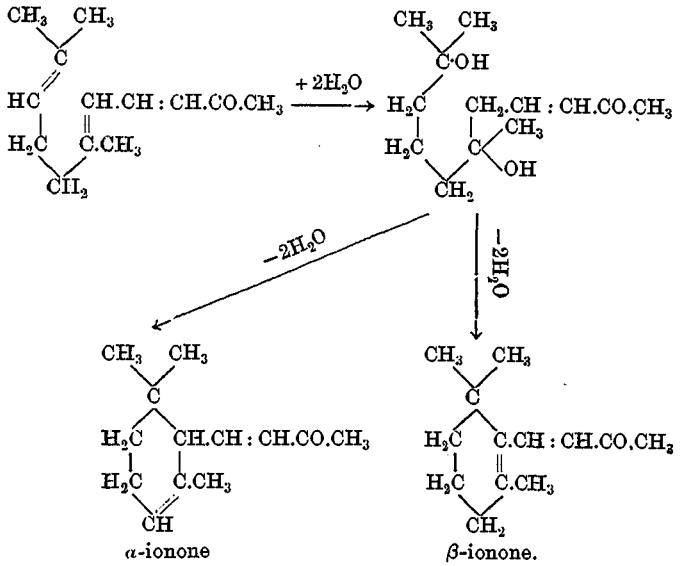
A further example of condensation by sodium hydroxide is afforded by ionone, used as a substitute for essence of violets, which is formed from citral and acetone.[37]

Pseudo-ionone is the first product, and this is then converted to a mixture of α- and β-ionone by boiling with dilute sulphuric acid :

$$(CH_3)_2C:CH.CH_2.CH_2.C(CH_3):CH.CHO + CH_3.CO.CH_3 =$$
$$(CH_3)_2C:CH.CH_2.CH_2.C(CH_3):CH.CH:CH.CO.CH_3 + H_2O.$$

The next stage is explained by the following scheme :



Potassium Compounds.

Potassium itself is rarely used in synthetic work, but the cyanide, acid sulphate, and hydroxide are often made use of.

A commercial process in which potassium may be regarded as a synthetic agent is Beilby's process for preparing cyanide, by heating a mixture of potassium carbonate and carbon in ammonia.

Potassamide is probably an intermediate compound, and the method corresponds to Castner's cyanide process:

$$K_2CO_3 + 2NH_3 + 2C = 2KNH_2 + 3CO + H_2$$
$$2KNH_2 + 2C = 2KCN + 2H_2$$

While the action of carbon monoxide upon heated potassium results in the formation of the carbonyl, moist carbon dioxide reacts with the metal to form carbonate and formate :

$$6K + 6CO = K_6(CO)_6$$
$$2K + H_2O + 2CO_2 = KHCO_3 + H.COOK$$
$$4K + H_2O + 3CO_2 = K_2CO_3 + 2H.COOK$$

Potassium Cyanide is especially useful for condensing aromatic aldehydes (benzoin condensation).[38]

Benzoin is formed from benzaldehyde :

$$2C_6H_5.CHO = C_6H_5.CHOH.CO.C_6H_5$$

Acetophenone condenses with benzoin in the presence of alcoholic cyanide, giving desylacetophenone :

$$C_6H_5.CHOH \atop | \\ CO.C_6H_5 + CH_3.CO.C_6H_5 = C_6H_5.CH.CH_2.CO.C_6H_5 \atop . \ | \\ CO.C_6H_5 + H_2O.$$

Mandelo-nitrile and benzyl cyanide condense in the presence of aqueous potassium cyanide, giving di-phenyl-succinic nitrile :

$$C_6H_5.CHOH \atop | \\ CN + CH_2.C_6H_5 \atop | \\ CN = C_6H_5.CH—CH.C_6H_5 \atop | \quad | \\ CN \quad CN + H_2O$$

It has been suggested that cyanhydrin formation is an intermediate stage in this class of condensation, and benzoin formation is represented by the following scheme :[39]

$$C_6H_5.CHO + KCN \rightarrow C_6H_5.CHOK \atop | \\ CN$$

$$C_6H_5.CHOK \atop | \\ CN + C_6H_5.CHO \rightarrow C_6H_5.COK—CHOH.C_6H_5 \atop | \\ CN$$

KCN is then eliminated—

$$C_6H_5.CO.CHOH.C_6H_5 + KCN.$$

ACID POTASSIUM SULPHATE may be used for the following condensations.

The leuco-base of malachite green from benzaldehyde and dimethyl-aniline:

$$C_6H_5.CHO + \begin{matrix} C_6H_5.N(CH_3)_2 \\ C_6H_5.N(CH_3)_2 \end{matrix} = C_6H_5.CH\begin{matrix} C_6H_4.N(CH_3)_2 \\ C_6H_4.N(CH_3)_2 \end{matrix} + H_2O$$

The resultant tetra-methyl-diamino-triphenyl methane is then oxidised to the carbinol, which is converted to malachite green by hydrogen chloride:

$$C_6H_5.C(OH)\begin{matrix} C_6H_4.N(CH_3)_2 \\ C_6H_4.N(CH_3)_2 \end{matrix} + HCl = C_6H_5.C\begin{matrix} C_6H_4.N(CH_3)_2 \\ C_6H_4{:}N(CH_3)_2Cl \end{matrix} + H_2O$$

Aromatic aldehydes condense with phenols, *e. g.* benzaldehyde and naphthol give hydroxy-dinaphthyl-phenyl methane:

$$C_6H_5.CHO + 2C_{10}H_7.OH = C_6H_5.CH(C_{10}H_6OH)_2 + H_2O.$$

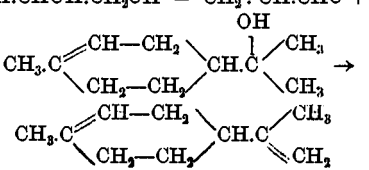
Pyruvic acid is formed by the removal of the elements of water from either tartaric or glyceric acids:

$$\begin{matrix} CHOH.COOH \\ | \\ CHOH.COOH \end{matrix} = CH_3.CO.COOH + CO_2 + H_2O$$

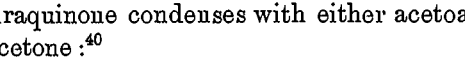
$$\begin{matrix} CH_2OH \\ | \\ CHOH \\ | \\ COOH \end{matrix} = CH_3.CO.COOH + H_2O.$$

By a similar elimination of water, glycerin yields acrolein and terpineol passes to dipentene:

$$CH_2OH.CHOH.CH_2OH = CH_2:CH.CHO + 2H_2O$$



Potassium Hydroxide can often be used for the same syntheses as sodium hydroxide, as for example, in condensing diketones with mono-ketones: Phenanthraquinone condenses with either acetoacetic ester or acetone:[40]



Phenanthroxylene acetoacetic ester.

Diacetone-phenanthraquinone.

Potassium hydroxide, when heated in aqueous solution with aromatic aldehydes, converts these in part to acids and in part to alcohols:

$$2C_6H_5.CHO + KOH = C_6H_5.COOK + C_5H_5.CH_2OH$$

Certain aliphatic aldehydes undergo a similar change. Isobutyric aldehyde, for example, is converted to isobutyric acid and di-isopropyl glycol:

$$3(CH_3)_2CH.CHO + KOH = (CH_3)_2CH.COOK + \begin{matrix}(CH_3)_2CH.CHOH \\ | \\ (CH_3)_2CH.CHOH\end{matrix}$$

This is a method for obtaining di-secondary glycols from certain aldehydes by means of alcoholic potassium hydroxide solution.[41]

Potassium nitrate may be used for the preparation of acid anhydrides from acid chlorides, by distilling the latter after mixing with the alkaline nitrate.[42]

Potassium and sodium disulphate bring about condensation with elimination of water. The following examples illustrate the use of this method:[43]

Triphenyl benzene from acetophenone, benzal

aniline from benzaldehyde and aniline, benzal malonic acid from benzaldehyde and malonic acid, benzal acetophenone from benzaldehyde and acetophenone.

Bibliography.

[1] Ann., 1853, **85**, 329.
[2] Ann., 1855, **96**, 365.
[3] Ann., 1863, **131**, 301.
[4] Monats., 1882, **3**, 625.
[5] Trans., 1888, **53**, 201.
[6] Ber., 1902, **35**, 2091.
[7] Ann., 1866, **138**, 204, 328.
[8] Phil. Trans., 1866, **156**, 37.
[9] Ann., 1877, **186**, 163; **190**, 257.
[10] Ann., 1880, **204**, 127.
[11] Ann., 1889, **249**, 54.
[12] Ann., 1883, **219**, 123.
[13] Ber., 1887, **20**, 646
[14] Ann., 1877, **190**, 276.
[15] Ber., 1885, **18**, 58.
[16] Trans., 1899, **75**, 839.
[17] Trans., 1904, **85**, 416.
[18] Ann., 1882, **211**, 306.
[19] Ann., 1888, **245**, 74.
[20] Ber., 1894, **27**, 229.
[21] Ber., 1893, **26**, 232.
[22] Ber., 1886, **19**, 1012.
[23] Ann., 1864, **130**, 105; Ber., 1889, **22**, 2917.
[24] Ber., 1887, **20**, 655.
[25] Ber., 1897, **30**, 1470.
[26] Ber., 1903, **36**, 4332.
[27] Ann., 1897, **297**, 1.
[28] Ber., 1905, **38**, 693.
[29] J. Soc. Chem. Ind., 1912, **31**, 622.
[30] Ber., 1880, **13**, 2342.
[31] Ber., 1881, **14**, 2468.
[32] Ber., 1882, **15**, 2856.
[33] Ber., 1882, **15**, 2574.

[34] Ber., 1887, **20**, 3386.
[35] Ann., 1899, **250**, 123.
[36] Ber., 1888, **21**, 1417.
[37] Ber., 1898, **31**, 808.
[38] Ber., 1892, **25**, 293; Ber., 1893, **26**, 60.
[39] Trans., 1903, **83**, 995.
[40] Ber., 1883, **16**, 276.
[41] Ber., 1896, Ref., 350.
[42] Ber., 1911, **44**, 3333.
[43] J. Amer. Chem. Soc., 1913, **35**, 81.

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CHAPTER II

COPPER AND SILVER

Both these metals bring about condensation by the removal of halogens, for which they have considerable affinity, and so function in this respect as sodium, but the reactions are not so vigorous.

The formation of butane from ethyl bromide and of ethylene from methylene iodide are examples of this condensation :

$$2C_2H_5Br + Cu = CuBr_2 + C_2H_5.C_2H_5$$
$$2CH_2I_2 + 4Cu = 2Cu_2I_2 + C_2H_4$$

Copper or silver can be used to condense β-iodo-propionic acid to adipic acid, and also for condensing α-brom-propionic ester to dimethyl succinic ester :[1]

$$2CH_2I.CH_2.COOH + 2Ag = \begin{matrix} CH_2.CH_2.COOH \\ | \\ CH_2.CH_2.COOH \end{matrix} + 2AgI$$

$$2CH_3.CHBr.COOR + 2Ag = \begin{matrix} CH_3.CH.COOR \\ | \\ CH_3.CH.COOR \end{matrix} + 2AgBr.$$

Other examples in which finely divided silver is used, are, the preparation of suberic ester from γ-brom-butyric ester, and di-isopropyl succinic ester from α-brom-isovaleric ester :[2]

$$2CH_2Br.CH_2.CH_2.COOR + 2Ag = \begin{matrix} CH_2.CH_2.CH_2.COOR \\ | \\ CH_2.CH_2.CH_2.COOR \end{matrix} + 2AgBr.$$

$$2(CH_3)_2CH.CHBr.COOR + 2Ag = \begin{matrix} (CH_3)_2CH.CH.COOR \\ | \\ (CH_3)_2CH.CH.COOR \end{matrix} + 2AgBr.$$

Copper has been used to facilitate the removal of hydrogen chloride and potassium chloride in the following condensations.[3]

Anthranilic acid from *o*-chlorbenzoic acid and ammonia:

$$C_6H_4\begin{matrix} Cl \\ COOH \end{matrix} + NH_3 = C_6H_4\begin{matrix} NH_2 \\ COOH \end{matrix} + HCl,$$

phenyl anthranilic acid is obtained if aniline be used in place of ammonia:

$$C_6H_4\begin{matrix} Cl \\ COOH \end{matrix} + C_6H_5.NH_2 = C_6H_4\begin{matrix} NH.C_6H_5 \\ COOH \end{matrix} + HCl.$$

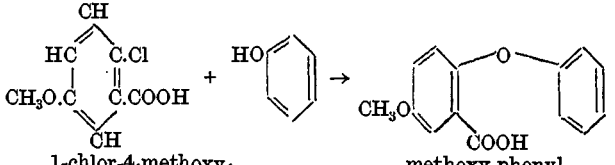
Further examples of the same class are:

$$C_6H_4\begin{matrix} Cl \\ COOH \end{matrix} + C_6H_5OH = C_6H_4\begin{matrix} OC_6H_5 \\ COOH \end{matrix} + HCl$$

o-chlor-benzoic acid — phenol — phenyl-salicylic acid.

$$C_6H_4\begin{matrix} Cl \\ COOK \end{matrix} + C_6H_5.SO_2K = C_6H_4\begin{matrix} SO_2.C_6H_5 \\ COOK \end{matrix} + KCl$$

o-chlor-benzoic acid — potassium phenyl sulphinate — phenyl-sulphi-benzoic acid.



1-chlor-4-methoxy-benzoic acid — methoxy-phenyl-salicylic acid.

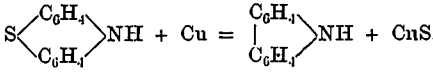
$$C_6H_5OK + C_6H_5Br = C_6H_5.O.C_6H_5 + KBr$$

Diphenyl ether.

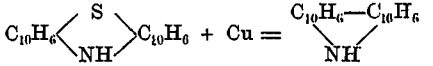
Copper is sometimes used to effect condensation by combining with sulphur. The two following syntheses of methane illustrate this reaction :

$$CS_2 + 2H_2S + 8Cu = CH_4 + 4Cu_2S$$
$$CS_2 + 2H_2O + 6Cu = CH_4 + 2Cu_2S + 2CuO.$$

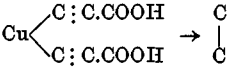
Carbazole is formed when thio-diphonylamine is mixed with copper powder and the mixture distilled in carbon dioxide :



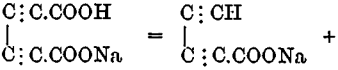
In a similar way β-dinaphthyl carbazole is formed from thio-β-dinaphthylamine :[4]



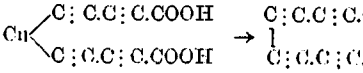
The action of potassium ferricyanide upon copper acetylene derivatives is interesting. Diacotylenodicarboxylic acid is obtained from the copper derivative of propiolic acid by treatment with ferricyanide :[5]



If the acid sodium salt of this be digested with water, carbon dioxide is liberated and the sodium salt of diacetylene-monocarboxylic acid is formed :



The copper derivative of this compound can also be condensed in the presence of ferricyanide, and tetr-acetylene-dicarboxylic acid results :

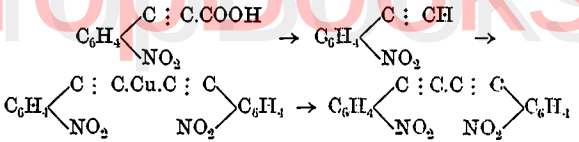


In using this method, the copper derivative (1 mol.) is added to a solution of potassium ferricyanide (1 mol.) containing potassium hydroxide (1 mol.), and the mixture is allowed to stand some hours.[6]

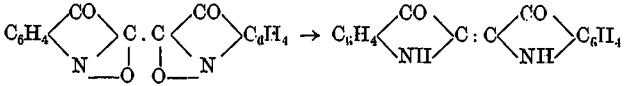
By the same process it is possible to prepare diphenyl-diacetylene from the copper derivative of phenyl-acetylene:

$$C_6H_5.C : C.Cu.C : C.C_6H_5 \rightarrow C_6H_5.C : C.C : C.C_6H_5.$$

Diphenyl-diacetylene is the parent hydrocarbon of indigo blue, and the dye itself can be prepared by means of this reaction, starting with o-nitro-phenyl-propiolic acid. By loss of carbon dioxide the acid becomes o-nitro-phenyl-acetylene, the copper derivative of which passes to di-ortho-nitrophenyl-diacetylene:



The last substance is changed to the isomeric di-isatogen by alkalis and this becomes indigo when reduced:



The use of copper salts and of copper itself for the replacement of the diazo-group of aromatic compounds, by chlorine, bromine, cyanogen, etc., is important.

Halogen substitution products of benzene were first prepared by the aid of copper salts in 1884,

when Sandmeyer discovered the reaction which is still named after him :[7]

$$C_6H_5.N:N.Cl \rightarrow C_6H_5Cl + N_2.$$

Gattermann,[8] in 1890, showed that the same reaction could be carried out, using copper powder instead of the salts of that metal, and the method was applied in substituting by, -Cl, -Br, -CN, -NO_2 and -CNS groups.

The yields by this method were superior to those obtained by the Sandmeyer method, probably because the copper powder was added to the diazonium solution in the cold, whereas Sandmeyer recommended adding the diazonium solution to a hot solution of the copper salt.

Later, Erdman, also Armstrong and Wynne (1892–93) used cold solutions of the copper salts and found the yields by Sandmeyer's method very much improved.[9]

Erdman also showed that there was a definite *optimum* temperature at which, by Sandmeyer's method, the maximum yield of halogen compound was formed, the *optimum* temperature referring to the temperature of the copper salt solution when the diazonium salt was added.

Heller (1910) states that by increasing sufficiently the amount of hydrochloric acid used, quantitative yields of chlor-compounds are possible by Sandmeyer's method.[10]

Sometimes condensation takes place in the presence of cuprous chloride, simultaneously with halogenation by Sandmeyer's method. When, for example, o-nitraniline is diazotised and treated with cuprous

chloride a considerable quantity of Dinitro-diphenyl results as well as o-chlor-nitro-benzeno.[11]

Heated metallic copper acts as a catalyst in the oxidation of primary alcohols to aldehydes by air or oxygen, but it has also been shown by Sabatier, that moderately heated copper in a finely divided state effects the dehydrogenation of primary and secondary alcohols, yielding aldehydes and ketones respectively.

Powdered silver was found by Gomberg to yield results when sodium failed, in preparing the peculiar and interesting substance called by him triphenyl-methyl. Both triphenyl brom-methane and triphenyl chlor-methane were used to effect the following change:

$$2(C_6H_5)_3C.Br + 2Ag = (C_6H_5)_3C.C(C_6H_5)_3 + 2AgBr.$$

The hexaphenyl ethane obtained was far more reactive than was to be expected, and on account of its properties Gomberg named it triphenyl methyl. Since then much work and discussion have centred around this substance, which is now generally regarded as being hexaphenyl-ethane.

Various constitutional formulæ have been suggested and the molecular structure of the hydrocarbon is still in dispute, but opinion appears to give preference to a formula which ascribes a *quinonoid* structure to one or two of the phenyl rings.[12]

Silver cyanide seems capable of acting in the same way as molecular silver. For example, it brings about the condensation of iodo-acetoacetic ester forming diaceto-succinic ester:[13]

$$\begin{matrix} CH_3.CO.CHI.COOC_2H_5 \\ CH_3.CO.CHI.COOC_2H_5 \end{matrix} \rightarrow \begin{matrix} CH_3.CO.CH.COOC_2H_5 \\ | \\ CH_3.CO.CH.COOC_2H_5 \end{matrix}$$

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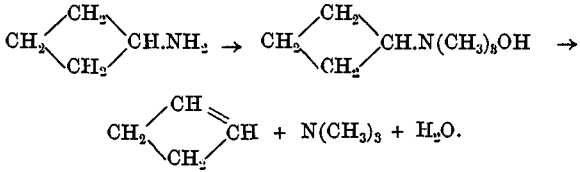
Silver hydroxide is used in *exhaustive methylation*, a process often utilised in order to obtain an unsaturated cyclic hydrocarbon from an amine by treating it with methyl iodide and silver hydroxide; the trimethyl-ammonium hydroxide obtained is then decomposed by distillation.

Cyclo-butylamine, for example, is converted to cyclo-butyl-ammonium hydroxide, and this on distilling is decomposed into cyclo-butylene, trimethylamine and water:[14]



Silver oxide suspended in water receives limited application as a hydrolysing agent, and in alkaline solution it is used as an oxidising agent, especially for converting aldehydes into acids.[15]

Bibliography.

[1] Ann., 1869, **149**, 220; Ber., 1895, **28**, Ref. 466.
[2] Ber., 1880, **13**, 473; Ber., 1889, 22, 48.
[3] Ber., 1904, **37**, 853.
[4] Ber., 1886, **19**, 2243.
[5] Ber., 1885, **18**, 678, 2269.
[6] Ber., 1882, **15**, 57.
[7] Ber., 1884, **17**, 1633.
[8] Ber., 1890, **23**, 1218.
[9] Trans., 1892, **61**, 1072.
[10] Zeit. angew. Chem., 1910, **23**, 389.
[11] Ber., 1901, **34**, 3802.
[12] J. Amer. Chem. Soc., 22, 957; Ber., 1900, **33**, 3150; Ber., 1901, **34**, 3818.
[13] Ann., 1889, **253**, 182.
[14] Ber., 1882, **15**, 1830.

CHAPTER III

MAGNESIUM. CALCIUM. BARIUM

THE great value of magnesium as a synthetic reagent was indicated in 1900, when Grignard showed how various hydrocarbons and alcohols could be prepared from the compounds obtained by allowing the metal to react with alkyl halides in the presence of dry ether.[1] In the previous year Barbier had shown that by the interaction of methyl heptenone, magnesium, and methyl iodide in ether, and subsequent decomposition of the resulting product by dilute acid, a tertiary alcohol was obtained, dimethyl heptenol :[2]

$$(CH_3)_2C:CH.CH_2.CH_2.CO.CH_3 \rightarrow (CH_3)_2C:CH.CH_2CH_2.C(OH)(CH_3)_2$$

The metal has to a great extent replaced zinc, which was used in 1849 by Frankland in the preparation of paraffin hydrocarbons and the zinc alkyls, and subsequently by Wagner for preparing secondary alcohol from aldehydes, by Saytzeff in preparing tertiary alcohols from ketones, and by Butlerow in the preparation of both ketones and tertiary alcohols from acid chlorides.

The advantage of magnesium over zinc depends

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upon the fact that the organo-magnesium compounds are not spontaneously inflammable; it is not essential that they should be isolated during syntheses, while they are more readily prepared than the corresponding zinc compounds, and they are more reactive, and therefore capable of much wider application.

In practice, the metal in the form of ribbon or borings is added gradually to a solution of well dried alkyl or aryl halide in dry ether; a brisk reaction usually takes place, owing to the formation of the magnesium compound of type R.Mg.X (X=Cl, Br, I).

When all the magnesium has been added and a clear solution obtained, the organic compound to be used in the synthesis (ketone, ester, etc.) is added gradually, and the mixture cooled in ice to modify the reaction if necessary.

When the vigorous reaction has subsided, it may be completed by heating on the water-bath for half an hour, or it may be allowed to stand over-night. The next stage is to add ice-cold dilute acid to the reaction mixture gradually, to decompose the complex intermediate compound formed, and the end-product is then isolated by suitable means. If magnesium ribbon is used, it must be first well cleaned with emery-paper, while borings must be washed first with alcohol and then with ether to remove all oil, and then thoroughly dried.

All the reagents used must be well dried, and the reaction should be conducted under a reflux condenser fitted with a top tube containing calcium chloride to prevent access of moisture, and some soda-lime to keep out carbon dioxide. The ether used should be

purified by treatment with powdered potassium permanganate, followed by treatment with solid potash to remove aldehyde, alcohol, and most of the water. The ether is then allowed to stand over calcium chloride for two days, and finally over sodium wire for about a week. Traces of moisture are very harmful, and the presence of moisture is indicated by a turbidity which appears when the magnesium is first added.

When the magnesium alkyl compound does not form readily, *i. e.* in using aryl halides, a crystal of iodine is often added to start the reaction. Other solvents than ether have been used, *i. e.* anisole, phenyl amyl ether, and dimethyl-aniline. The solvent apparently combines with the compound MgRX forming intermediate products $R_2O.MgRX$ and $R_3N.MgRX$, and acts as a catalyst, since it has been found that the reactions proceed in benzene or xylene provided a small amount of ether or dimethyl-aniline be added.

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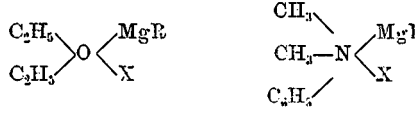
The constitution of these compounds is represented, according to the suggestion of Baeyer and Villiger,[3] by an oxonium formula with the halogen directly attached to quadrivalent oxygen, a suggestion supported by Blaise. The dimethyl-aniline compound is similarly represented:



Although the formation of the compound MgRX is the normal course, there is a tendency for the magnesium to form a hydrocarbon by the removal of

halogen from two molecules of RX, which is more marked as the molecular magnitude of R increases. When working with brom-benzene and benzyl chloride a considerable quantity of diphenyl and dibenzyl result, but this may be avoided by adopting Barbier's original method of omitting the first stage (preparation of MgRX) and mixing all the reagents at once. This fact was emphasized by Kipping recently, and the method has also been used with allyl bromide and iodide syntheses with success, although the allyl halides do not form a compound of the type MgRX in the presence of ether.[4]

The following syntheses were carried out by means of zinc, prior to 1900, and are now more conveniently accomplished by the aid of magnesium:

PARAFFIN HYDROCARBONS.

$$MgR_2 + 2H_2O = 2RH + Mg(OH)_2$$
$$RMgX + H_2O = RH + MgX(OH)$$
$$RMgX + RNH_2 = R.R + MgXNH_2$$
$$MgR_2 + 2R_3CX = 2R_4C + MgX_2$$

SECONDARY ALCOHOLS FROM ALDEHYDES.

$$R.CHO + R'.Mg.X \rightarrow R.C(O.Mg.X)(R')(H) \xrightarrow{+HCl} R.C(R')(H)(OH) + MgXCl.$$

If formaldehyde be used, a primary alcohol results:[5]

$$H.CHO + R.Mg.X \rightarrow H.C(O.Mg.X)(R)(H) \xrightarrow{+HCl} R.CH_2OH + MgXCl.$$

Tertiary Alcohols from Ketones.

$$R.CO.R + R'.Mg.X \rightarrow R.C(OMgX)(R)(R') \xrightarrow{+ HCl} R_2R'COH + MgXCl.$$

Ketones and Tertiary Alcohols from Acid Chlorides.

$$R.COCl + R'.Mg.X \rightarrow R.C(OMgX)(Cl)(R') \rightarrow R.CO.R' + MgXCl.$$

With a second molecule of $MgR'X$ the following change takes place:

$$R.C(OMgX)(Cl)(R') \xrightarrow{+ MgR'X} R.C(OMgX)(R')_2 \xrightarrow{+ HCl} R'_2RCOH + MgXCl.$$

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Tertiary Alcohols from Esters.

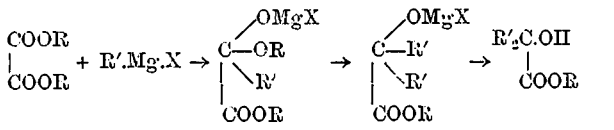
$$R.COOR' + R''.Mg.X \rightarrow R.C(OMgX)(OR')(R'') \xrightarrow{+ MgR''X} R.C(OMgX)(R'')_2$$

$$R.C(OMgX)(R'')_2 \xrightarrow{+ HCl} RR''_2COH + MgXCl.$$

With formic ester a secondary alcohol is obtained:

$$H.COOR + R'.Mg.X \rightarrow H.C(OMgX)(OR)(R') \rightarrow H.C(OMgX)(R')_2 \rightarrow R'_2CHOH.$$

A dicarboxylic ester like oxalic ester may have only one carboxyl group acted upon at a time:



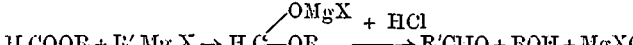
Dialkyl glycollic ester.

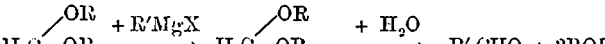
Since 1900 various syntheses have been added, of which the following are typical examples:

TERTIARY ALCOHOLS FROM CARBONYL CHLORIDE.

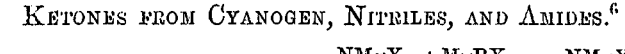
$$COCl_2 + 3R.Mg.X = R_2COMg.X + 2MgXCl$$
$$R_2COMgX + HCl = R_3C.OH + MgXCl.$$

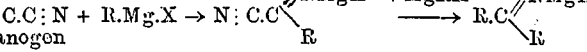
ALDEHYDES FROM FORMIC AND ORTHO-FORMIC ESTERS.

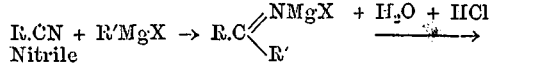


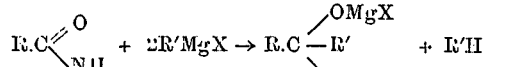


KETONES FROM CYANOGEN, NITRILES, AND AMIDES.[6]









$$R.C\begin{cases}OMgX\\ -R'\\ NHMgX\end{cases} + 2HCl = R.CO.R' + NH_2 + 2MgXCl.$$

DIAZO-AMINO COMPOUNDS FROM AZOIMIDES.

$$R.N\begin{cases}N\\ \|\\ N\end{cases} + R'MgX \rightarrow R.N(MgX)N:N.R'$$

$$R.N(MgX)N:N.R' + H_2O \rightarrow R.NH.N:NR' + Mg(OH)X.$$

ANILIDES FROM AMYL CARBIMIDES.

$$C_6H_5.N:CO \rightarrow C_6H_5.N:C\begin{cases}OMgX\\ R\end{cases} \rightarrow C_6H_5.NH.COR.$$

HYDROXYLAMINE DERIVATIVES FROM AMYL NITRITE.

$$C_5H_{11}.O.NO + 2MgRX = R_2NOMgX + MgOC_5H_{11}X$$
$$R_2NOMgX + HCl = R_2NOH + MgXCl.$$

Esters of the type R.COOR are obtained by the action of MgRX upon esters of meta-carbonic acid :

$$CO(OEt)_2 + RMgX \rightarrow (EtO)_2C\begin{cases}OMgX\\ R\end{cases} \rightarrow EtO.C\begin{cases}=O\\ R\end{cases}$$

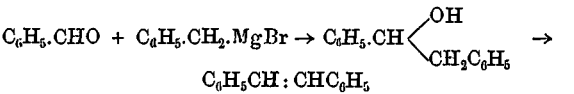
Triphenyl methyl chloride in benzene solution reacts with an ether solution of RMgCl thus :[7]

$$(C_6H_5)_3C.Cl + RMgCl = (C_6H_5)_3C.R + MgCl_2$$

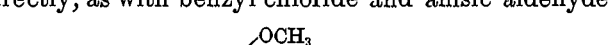
Hydrocarbons are formed by the action of methyl sulphate upon RMgX :

$$(CH_3)_2SO_4 + RMgX = R.CH_3 + CH_3(MgX)SO_4.$$

Unsaturated hydrocarbons may be obtained from aromatic aldehydes *viâ* the carbinols, which on distillation sometimes decompose, as phenyl-benzyl-carbinol does, into stilbene and water :[8]

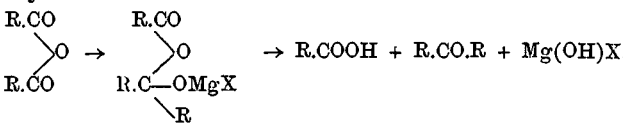


Sometimes the unsaturated hydrocarbon is formed directly, as with benzyl chloride and anisic aldehyde:

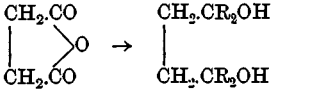


Benzyl alcohol may be obtained from benzyl chloride by the action of oxygen:

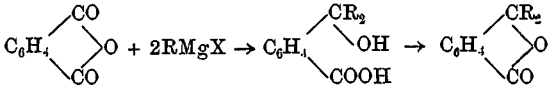
Tertiary alcohols and ketones result from acid anhydrides:



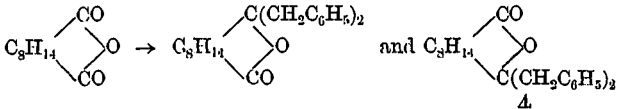
From succinic anhydride a ditertiary glycol results:



From phthalic anhydride similarly dimethyl-, diethyl-, and dipropyl-phthalide are obtained:



Camphoric anhydride with benzyl chloride gives two isomeric campholides:



α-Diketones give ditertiary glycols, as in the case of benzil to tetraphenyl glycol:

$$\begin{matrix} C_6H_5.CO \\ | \\ C_6H_5.CO \end{matrix} \rightarrow \begin{matrix} C_6H_5C(OH)R \\ | \\ C_6H_5C(OH)R \end{matrix}$$

If only one carbonyl group be attacked, phenyl benzoin results:

$$C_6H_5CO.CROH.C_6H_5$$

Acids are formed by the action of carbon dioxide upon R.Mg.X:

$$R.Mg.X + CO_2 \rightarrow R.C\begin{matrix} OMgX \\ \| \\ O \end{matrix} \xrightarrow{+ HCl} R.COOH + MgXCl.$$

Many organo-metallic compounds can be prepared by digesting an ethereal solution of the magnesium alkyl or aryl halide with the metallic halogen compound.

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The following compounds have been prepared in this way:

$$Sn(C_2H_5)_4,\ Sn(C_6H_5)_4,\ Pb(C_6H_5)_4,\ Pb(CH_3)_4,\ Hg(C_6H_5)_2,$$

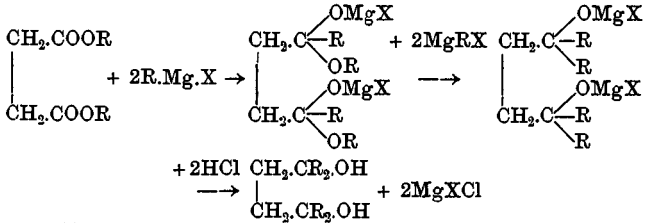
and an optically active silicon compound in which four different radicles are present, $Si(C_2H_5)\ (C_3H_7)\ (C_6H_5)\ (CH_2C_6H_5)$.[9]

Pivalic (trimethylacetic) acid is formed from tertiary butyl chloride and magnesium (yield, 30 per cent.):

$$(CH_3)_3C.Cl \xrightarrow{+ Mg} (CH_3)_3C.Mg.Cl \xrightarrow{+ CO_2} (CH_3)_3C.C\begin{matrix} OMgCl \\ \| \\ O \end{matrix} \rightarrow$$

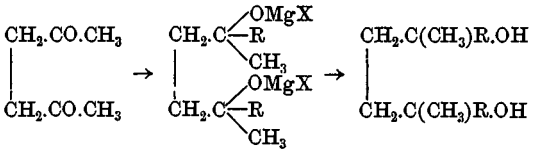
$$(CH_3)_3C.C\begin{matrix} OH \\ \| \\ O \end{matrix}$$

Tetramethyl-methylene-glycol from succinic ester:



(A ditertiary glycol is also obtained from oxalic ester.)

By the same reaction this can be obtained from acetonyl acetone:



The ketonic group of α-ketonic esters is attacked in preference to the carboxyl group. From pyruvic ester is obtained α-methyl lactic ester:

$$CH_3.CO.COOR + MeMgX \rightarrow CH_3.C(OMgX)(COOR)(Me) \rightarrow CH_3.C(Me)(OH).COOR$$

γ-Ketonic esters, such as lævulinic ester, behave in the same way:

$$CH_3.CO.CH_2.CH_2.COOR \rightarrow CH_3.C(OH)(R)-CH_2.CH_2.COOR$$

β-Ketonic esters, such as acetoacetic ester, show a somewhat different behaviour. The ethyl and menthyl esters both react with MgRX as if possessed of an enolic structure, and the magnesium compound formed

is decomposed by dilute acid, giving the original acetoacetic ester :[10]

$$CH_3.C(OH):CH.COOR + R'MgX = CH_3.C(OMgX):CH.COOR + R'H$$
$$CH_3C(OMgX):CH.COOR + HCl = CH_3.CO.CH_2.COOR + MgXCl$$

When, however, enolisation is retarded by an alkyl substituent in the methylene group, the reaction follows the same course as α- and γ-ketonic esters :

$$CH_3.CO.CHR.COOR \rightarrow CH_3.CR'(OH).CHR.COOR$$

If the carboxyl group be next attacked by $MgR'X$, the following change takes place, resulting in a substituted trimethylene glycol :

$$CH_3.CR'.CHR.COOR \rightarrow CH_3.CR'.CHR.CR'_2$$
(with OH under CR'.CHR.COOR; OH under CR'.CHR; OH under CR'$_2$)

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The tendency to form organo-metallic compounds, seen in the metals of group 1 (alkali metals) reaches a maximum in the metals of group 2 ; it diminishes on passing through groups 3, 4 and 5, and none of the metals in groups 6 and 7 combines with organic radicles. The property reappears in group 8, which contains the transitional elements.

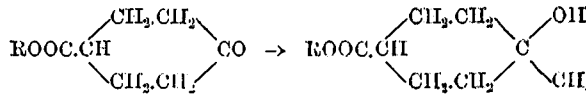
Aluminium, thallium, indium and lithium form complexes with alkyl or aryl halides, which are decomposed by water, with the formation of hydrocarbons.

These compounds are not produced in the presence of ether, but by heating the halogen derivatives with the metal.[11]

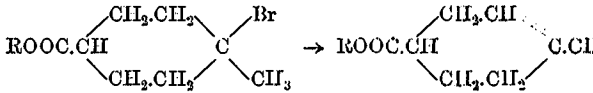
Two important applications of the *Grignard reagent* to synthesis in the terpene series may be mentioned.

The formation of dipentene from δ-keto-hexahydrobenzoic acid (see p. 14) by Perkin involved the

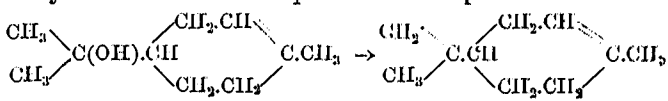
following stages: The ester was treated with magnesium methyl bromide, and the addition compound gave on hydrolysis δ-hydroxy-hexahydro-*p*-toluic ester:



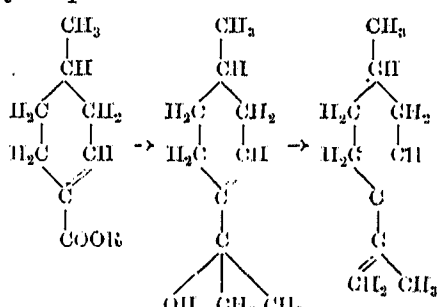
This ester was then converted into δ-brom-hexahydro-*p*-toluic ester by the action of hydrogen bromide, and from this, by removal of HBr with alkali or pyridine, Δ^{8}-tetra-hydro-*p*-toluic ester was obtained:



Treatment of this ester with 2MgMeBr gave terpineol, which was converted into dipentene by dehydration with acid potassium sulphate:



The synthesis of $\Delta^{1:8(9)}$-*p*-menthadiene from ethyl-Δ^{3}-tetrahydro-*p*-toluate involved the following stages:



Calcium and Barium.

These metals, so alike chemically and physically, have been closely associated together in the solving of the problem of atmospheric nitrogen fixation.

Calcium has received some application in organic synthesis similar to that of magnesium; alkyl and aryl compounds, CaR_2, have been prepared, and it seems likely that many of the magnesium syntheses, already mentioned, could be accomplished by the use of calcium.

The compounds of calcium and barium, instrumental in bringing about *nitrogen fixation*, are the carbides, the preparation of which has been rendered possible by the advent of the electric furnace. This means of attaining very high temperatures came into general use during the eighties of last century, and rendered possible the preparation, on a large scale, of many new and useful substances.

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In 1895, Frank and Caro found that when barium carbide was heated to redness in air the main product was barium cyanide, but simultaneously a certain amount of barium cyanamide was formed. These two reactions, therefore, proceeded side by side:

$$BaC_2 + N_2 = Ba(CN)_2 \; ; \; BaC_2 + N_2 = BaN.CN + C$$

These workers subsequently found that when calcium carbide was used the cyanamide was the main product, while the cyanide became the by-product.

These efforts to prepare a nitrogenous land fertilizer promised success, since the cyanamide decom-

posed easily in the presence of water, yielding ammonia and lime:

$$CaN.CN + 3H_2O = CaCO_3 + 2NH_3$$

Later work has shown that cyanamide of lime is not only a valuable fertilizer product, but that it can be used for a variety of purposes and transformed into various useful products.

Eleven European factories were making the substance in 1909, and their yearly output was estimated at 166,000 tons, while in the same year the American Cyanamide Company erected at Niagara, plant capable of yielding 20,000 tons per annum. The substance is sold for agricultural uses under the name of *nitrogen lime* (German, Kalkstickstoff), and has been shown to be equal in value to an equivalent of calcium nitrate.

Since 1901 it has been found unnecessary to prepare the carbide itself in the first place, and necessary to exclude oxygen, so that now the process involves the heating together, in an electric furnace, of lime and carbon in atmospheric nitrogen, when the following change takes place:

$$CaO + 2C + N_2 = CaN.CN + CO.$$

The complete decomposition of the cyanamide into calcium carbonate and ammonia may be accomplished in stages by suitably arranging the conditions, so that the first substance to be formed is cyanamide itself, which is then transformed into urea, and the third stage involves the hydrolysis of urea into carbon dioxide and ammonia:

$$CaN.CN + 2H_2O = Ca(OH)_2 + NH_2.CN$$
$$NH_2.CN + H_2O = CO(NH_2)_2$$
$$CO(NH_2)_2 + H_2O = CO_2 + 2NH_3$$

Under ordinary soil conditions all the above stages are realised, but by heating with water under pressure, complete decomposition into calcium carbonate and ammonia takes place.

The chief uses of calcium cyanamide are as follows :

(1) By decomposition with steam it is used for preparing ammonia and ammonium salts.

(2) When fused with sodium carbonate, or chloride, and carbon it yields sodium cyanide :

$$CaN.CN + Na_2CO_3 + C = CaCO_3 + 2NaCN.$$

Hundreds of tons of cyanide are manufactured annually in this way in Europe, and in Mexico it is made in the mining districts.

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(3) It receives some application in the case-hardening of steel.

(4) By the action of dilute acids, dicyanamide is formed :

$$2CaN.CN + 4H_2O = 2Ca(OH)_2 + (CN.NH_2)_2$$

Dicyanamide is used in large quantities by dyers and explosive manufacturers. Its presence in gunpowder tends to lower the temperature of the gun-barrel.

(5) Artificial urea made from cyanamide is used in large quantities for certain pharmaceutical preparations :

$$CaN.CN + 3H_2O = Ca(OH)_2 + CO(NH_2)_2$$

(6) Large quantities of guanidine are made from cyanamide. Two methods are available for this

preparation ; either the cyanamide may be treated with ammonia, or it may be reduced with zinc and hydrochloric acid. In the latter method, methylamine is produced at the same time by reduction of the hydrogen cyanide formed :

$$CN.NH_2 + NH_3 = HN:C\begin{matrix}NH_2\\NH_2\end{matrix}$$

$$2CN.NH_2 + H_2 = HN:C\begin{matrix}NH_2\\NH_2\end{matrix} + HCN$$

$$HCN + 2H_2 = CH_3.NH_2.$$

(7) Creatine is prepared by combining cyanamide with sarcosine (methyl glycine) at 100° C. :

$$CN.NH_2 + CH_3.NH.CH_2.COOH = \begin{matrix}NH_2\\HN\end{matrix}\!\!>\!C.N(CH_3).CH_2.COOH.$$

(8) Another method for preparing cyanide depends upon the heating of dicyanamide with alkaline carbonate and carbon. Ammonia is formed at the same time and is generally absorbed in sulphuric acid.

$$2(CN.NH_2)_2 + 2K_2CO_3 + 4C = 4KCN + 2NH_3 + H_2 + 6CO + N_2$$

A process patented in 1903 by the Ampère Electro-Chemical Co. (U.S. patent 719223) for the preparation of barium cyanide and acetone is as follows :

Barium hydroxide and carbonate are heated with coke in a revolving electric furnace. The barium carbide formed, rolls down into a cooler region and there comes into contact with a stream of atmospheric nitrogen, and the resulting cyanide is withdrawn :

$$BaC_2 + N_2 = Ba(CN)_2$$

The cyanide is next treated with acetic acid to liberate the hydrogen cyanide, which is then passed into alkali :

$$Ba(CN)_2 + 2CH_3COOH = (CH_3COO)_2Ba + 2HCN$$

The acetate is then submitted to distillation, whereby acetone is formed, and the barium carbonate is used over again :

$$(CH_3COO)_2Ba = CH_3.CO.CH_3 + BaCO_3$$

The by-product of the first stage, barium cyanamide, is separated from the cyanide and converted into alkali cyanide by fusion with carbonate :

$$BaN.CN + Na_2CO_3 + C = BaCO_3 + 2NaCN.$$

The preparation of nitrides from atmospheric nitrogen making use of calcium or magnesium, has been the subject of much investigation and of many patents.

The nitrides are easily decomposed by the weakest acids, even by carbonic acid, liberating ammonia, and often they can be decomposed by water.

Some processes depend on the fact that the oxide of a nitrido-forming metal is reduced to the metallic condition, when heated in the electric furnace with carbon in the requisite quantity, and if a stream of nitrogen be then blown through the fused mass, nitride is formed.

Magnesium has, for example, been utilised in this way :

$$2MgO + C = 2Mg + CO_2; \; 6Mg + 3N_2 = 2Mg_3N_2$$
$$Mg_3N_2 + 6H_2O = 3Mg(OH)_2 + 2NH_3$$

The French Patent, 350966, depends upon the production of calcium hydride which is formed by

heating the metal in hydrogen; the hydride is next converted into the nitride by a stream of nitrogen, ammonia being formed at the same time:

$$Ca + H_2 = CaH_2 \; ; \; 3CaH_2 + 2N_2 = Ca_3N_2 + 2NH_3$$
$$Ca_3N_2 + 6H_2 = 3CaH_2 + 2NH_3$$

The nitride is then heated in hydrogen to decomposo it in the manner indicated above; the method is one, therefore, of continually fixing atmospheric nitrogen and converting it into ammonia. In developing this method it has been found that either calcium or magnesium may be used, or a mixture of the two metals; also that it is immaterial whether the hydrogen and nitrogen pass over the metal separately or together; and instead of hydrogen it is possible to use water-gas.

The reaction may, therefore, be regarded as a synthesis of ammonia from its elements in the presence of magnesium or calcium.

Another process for the fixation of atmospheric nitrogen is the subject of an English Patent, 1894, 13315.

A heated air-blast is passed into the bottom of a vertical furnace containing a mixture of alkaline carbonate and coal (the carbonate may be replaced by or mixed with oxide, hydrate or nitrate), whereby a cyanide results, which is carried up in the form of a fume and at a suitable height is decomposed by a jet of steam, into carbonate and ammonia, the latter being collected in condensers:

$$K_2CO_3 + 4C + N_2 = 2KCN + 3CO$$
$$KCN + 2H_2O = HCONH_2 + KOH$$
$$HCONH_2 = CO + NH_3$$
$$CO + O = CO_2 \; ; \; CO_2 + 2KOH = K_2CO_3 + H_2O.$$

The K_2CO_3 is allowed to fall down to the bottom of the furnace and the process is repeated. The entire reaction may be represented by the following equation :

$$2KCN + 3H_2O + O_2 = K_2CO_3 + 2NH_3 + CO_2$$

This process may evidently be used to yield ammonia and formic acid if the reaction is regulated to bring about the following change :[12]

$$KCN + 2H_2O = HCOOK + NH_3$$

Two applications of the calcium and barium salts of various organic acids are common and of great importance.

Firstly, the calcium and barium salts of organic acid are frequently used in the preparation of the acids themselves, by treatment with mineral acids such as sulphuric, hydrochloric or phosphoric. This method was first utilised by the Swedish chemist, Scheele (about 1770), who discovered by this means tartaric, citric, malic and oxalic acids.

Secondly, by the dry distillation of the calcium and barium salts of organic acids, ketones are formed :

$$(CH_3COO)_2Ca = CaCO_3 + CH_3.CO.CH_3$$

If the salt of formic acid be mixed in molecular quantity with the other salt then an aldehyde is produced :

$$(HCOO)_2Ca + (CH_3COO)_2Ca = 2CH_3.CHO + 2CaCO_3$$

Certain cyclic ketones have been formed in this way, and from them, the cyclic hydrocarbons.

For example, the calcium salt of adipic acid yields on distillation, adipoketone (keto-pentamethylene),

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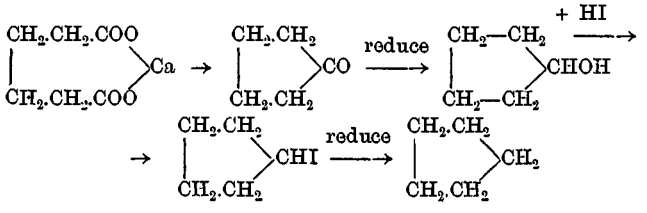
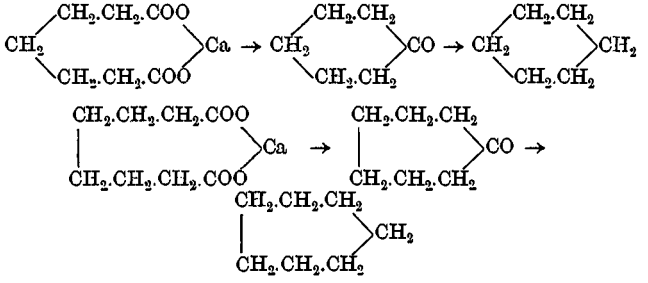
and this by reduction and subsequent use of hydrogen iodide gives pentamethylene:

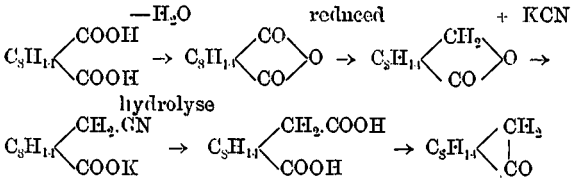


In a similar manner hexamethylene can be prepared from pimelic acid, and heptamethylene from suberic acid:



By means of this reaction Haller obtained camphor from camphoric acid.[13]

The complete process was as follows; camphoric anhydride from camphoric acid was reduced with sodium amalgam to campholide, and this combined with potassium cyanide gave homocamphoric nitrile. The nitrile was hydrolysed, and the calcium salt of the resulting homocamphoric acid, on heating, gave camphor:



The hydroxides of magnesium, calcium and barium, have played an important part in the synthesis of sugars.

In 1861, Butlerow digested an aqueous solution of calcium hydroxide with trioxymethylene (a polymer of formaldehyde) and obtained a sweet yellowish syrup.[14]

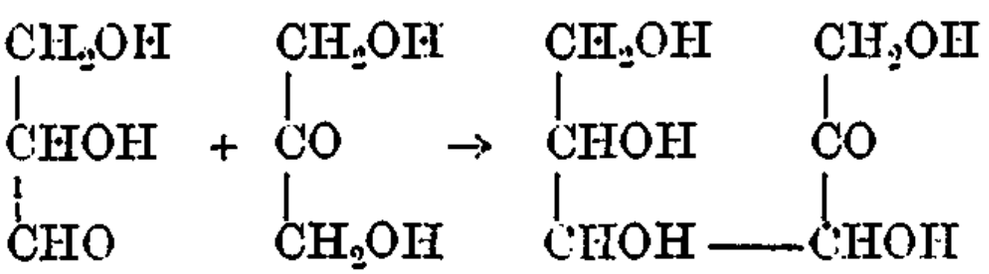
In 1886, Loew prepared a syrup which he termed formose, by shaking a 4 per cent. solution of formaldehyde with milk of lime and then filtering. After standing for five or six days, the solution was evaporated and a syrup obtained.[15]

A few years later (1889) he used magnesium hydroxide, and by the same method obtained a sweet syrup which was fermentable and which he termed methose.[16]

The above three syrups all appear to have contained *a*-acrose, which Emil Fischer isolated in a pure state in 1887, by the action of baryta water upon acrolein bromide, when a mixture of *a*- and *β*-acrose was obtained.[17]

$$2C_3H_4OBr_2 + 2Ba(OH)_2 = C_6H_{12}O_6 + 2BaBr_2$$

Fischer subsequently obtained *a*-acrose alone, by the polymerising influence of one per cent. sodium hydroxide upon glycerose, an oxidation product of glycerol.[18]



Bibliography.

[1] Compt. rend., 1900, **130**, 1322.
[2] Compt. rend., 1899, 123, 110.
[3] Bull. Soc. Chim., 1907 (iv), **1**, 610.
[4] Ber., 1909, **42**, 435.
[5] Compt. rend., 1902, **134**, 107.
[6] Compt. rend., 1901, **133**, 299.
[7] Ber., 1906, **39**, 1461.
[8] Ber., 1904, **37**, 453.
[9] Trans., 1901, **79**, 451; Proc., 1903, 290; Trans., 1907, **91**, 209.
[10] Trans., 1906, **89**, 380.
[11] Ber., 1905, **38**, 905; J. prakt. Chem., 1908 (ii), **78**, 97.
[12] Zeit. angew. Chem., 1912, **25**, 1268.
[13] Compt. rend., 1896, **122**, 446.
[14] Ann., 1861, **120**, 295.
[15] J. prakt. Chem., 1844, **33**, 321.
[16] Ber., 1889, **22**, 475.
[17] Ber., 1887, **20**, 1093, 2566, 3384; 1890, **23**, 2125.
[18] Ber., 1894, **27**, 3190.

CHAPTER IV

ZINC AND MERCURY

The use of zinc for preparing ketones and tertiary alcohols from acid chlorides, has received wider application since Michael showed how it might be used in a similar manner to magnesium, without isolating spontaneously inflammable organo-zinc compounds. It has been used largely by Blaise and his co-workers in synthesising ketones and cyclo-acetals; it is less reactive than magnesium, and is, therefore, complementary to that metal in synthetic work.

The zinc organo-halide is prepared for use by heating together the zinc-copper couple, the alkyl or aryl halide, ethyl acetate, and toluene for about an hour, the reaction being started if necessary with a crystal of iodine. All the reagents must be well dried, and the colourless viscous liquid which results is utilised by adding to it the acid chloride dissolved in toluene, and when the required amount has been added the intermediate zinc complex is decomposed by the addition of dilute sulphuric acid.[1]

Blaise synthesised $\alpha\beta$-unsaturated ketones, and ketone-alcohols as follows: A β-hydroxy-aliphatic ester is prepared by condensing a ketone with an

α-halogen substituted ester by means of zinc (Reformatsky's reaction) :

$$\begin{matrix}\mathrm{R.CHBr}\\ |\\ \mathrm{COOR}\end{matrix} + (\mathrm{CH_3})_2\mathrm{CO} \rightarrow (\mathrm{CH_3})_2\mathrm{C(OH).CHR.COOR}$$

The β-hydroxy-aliphatic acid is then acetylated and converted to the acid chloride by thionyl chloride, after which the acid chloride reacts with ZnRX, to produce an acetoxy-ketone which is hydrolysed to an $\alpha\beta$-unsaturated ketone :

$$\mathrm{HO.CHR.CHR'.COOH} \rightarrow \mathrm{AcO.CHR.CHR'.COCl} \xrightarrow{+\ \mathrm{ZnR''X}} \rightarrow \mathrm{AcO.CHR.CHR'.COR''} \rightarrow \mathrm{RCH:CR'.COR''}$$

If however, there is no hydrogen atom in the α-position, a saturated keto-alcohol results :

$$\mathrm{AcO.CH_2.CR_2.COR''} \rightarrow \mathrm{HO.CH_2.CR_2.COR''}$$

β-hydroxy-$\alpha\alpha$-dimethyl propionyl chloride, for example, changes in this manner.[2]

The semi-acid chlorides of succinic and glutaric acids yield keto-acids by treatment with ZnRI :

$$\begin{matrix}\mathrm{CH_2.COOR}\\ |\\ \mathrm{CH_2.COCl}\end{matrix} \rightarrow \begin{matrix}\mathrm{CH_2.COOR}\\ |\\ \mathrm{CH_2.COR}\end{matrix} \rightarrow \begin{matrix}\mathrm{CH_2.COOH}\\ |\\ \mathrm{CH_2.COR}\end{matrix}$$

Diketones are obtained from the acid chlorides of adipic acid and higher acids of the series :

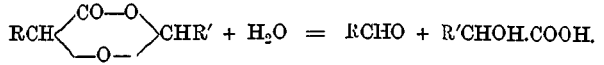
$$(\mathrm{CH_2})_n\begin{matrix}\mathrm{COCl}\\ \mathrm{COCl}\end{matrix} \rightarrow (\mathrm{CH_2})_n\begin{matrix}\mathrm{COR}\\ \mathrm{COR}\end{matrix}$$

This change is not applicable to succinic and glutaric acids.[3]

Compounds of the type R.CO.O.CHR.COCl give cyclo-acetals, probably by the following change :

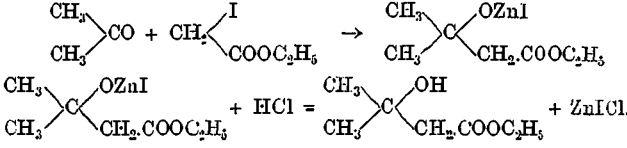
$$\mathrm{ZnIO.CR_2.O.CHR.COCl} \rightarrow \mathrm{R_2C}\begin{matrix}\mathrm{O—CO}\\ \mathrm{—O—}\end{matrix}\mathrm{CHR}$$

These cyclo-acetals may be hydrolysed, forming hydroxy-acid and aldehyde :[4]

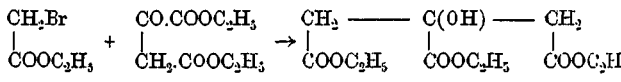


The use of zinc in those syntheses which are now generally carried out by the aid of magnesium, has already been mentioned, p. 45.

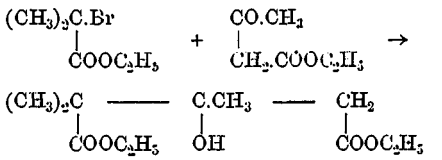
A further application of zinc is seen in a reaction first carried out by Reformatsky in 1887, in which halogen substituted esters are condensed with ketones or with ketonic esters. An example is afforded by the production of β-hydroxy-isovaleric ester from acetone and iodo-acetic ester; a zinc addition compound is probably formed, and on the addition of dilute acids is decomposed. This reaction is therefore represented in the following manner:



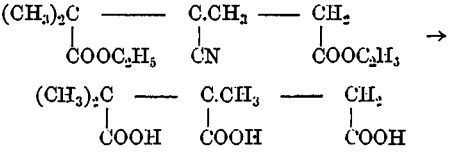
Citric ester has been synthesised in this way from brom-acetic ester and oxalyl-acetic ester :[5]



Another example is camphoronic acid (ααβ-trimethyl-tricarballylic acid), an oxidation product of camphoric acid, which can be synthesised from α-brom-isobutyric ester and acetoacetic ester.[5]



The hydroxyl group of this hydroxy-trimethyl glutaric ester is replaced by chlorine, this again by cyanogen, and the nitrile gives the required acid on hydrolysis, dl-camphoronic acid :



Magnesium has been used in place of zinc for this type of synthesis.[6]

Zinc is frequently used for bringing about condensation by the elimination of halogen or of hydrogen halide.

For the preparation of hydrocarbons it may replace sodium in the Wurtz-Fittig reaction :

$$2C_3H_5I + Zn = ZnI_2 + C_6H_{10}.$$

In reactions where hydrogen halide is eliminated, zinc plays a somewhat similar *rôle* to that of aluminium or aluminium chloride in the Friedel-Crafts reaction (Chapter V).

Naphthyl-phenyl-ketone is obtained from naphthalene and benzoyl chloride, in the presence of zinc :[7]

$$C_{10}H_8 + C_6H_5COCl = C_{10}H_7.CO.C_6H_5 + HCl.$$

Phenyl-tolyl-methane from benzyl chloride and toluene is another example :

$$C_6H_5.CH_2Cl + C_6H_5.CH_3 = C_6H_5.CH_2.C_6H_4.CH_3 + HCl.$$

A recent and interesting use of zinc is found in the preparation of keten, the simplest of the ketides, from brom-acetyl bromide.[8]

After an unsuccessful attempt to remove the chlorine from chlor-acetyl chloride, it was found possible to remove the bromine from brom-acetyl bromide by treatment with zinc turnings, in ethereal solution. For this purpose the brom-acetyl bromide (50 gms.) was dissolved in ether (250 gms.) or in acetic ester (200 c.cm.), and the mixture was then dropped on to zinc turnings, in a distillation flask. A vigorous reaction took place and the product was allowed to distil over, in a current of hydrogen gas.

The keten was isolated by passing the mixed vapours through a vessel immersed in liquid air and was found to be a gas at ordinary temperatures, which liquefied when cooled to — 56° and solidified at — 151°:

$$CH_2Br.COBr + Zn = CH_2:CO + ZnBr_2.$$

Methyl and ethyl keten can be prepared by the same method using α-brom-propionyl bromide and α-brom-butyryl bromide respectively, but the yields are smaller than with keten itself:

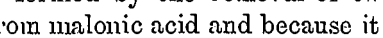
$$CH_3.CHBr.COBr + Zn = CH_3.CH:CO + ZnBr_2$$
$$C_2H_5.CHBr.COBr + Zn = C_2H_5.CH:CO + ZnBr_2.$$

Carbon suboxide (C_3O_2) may be regarded as keten in which the two hydrogens of the methylene group have been replaced by the carbonyl group:

$H_2C:CO$	$CO:C:CO$
Keten	Carbon suboxide.

This substance was prepared in 1906, by heating malonic acid with phosphorus pentoxide at 300° under

reduced pressure (12 mm.). Carbon suboxide is a colourless gas at ordinary temperatures, its boiling point is + 7° and the melting point of the solid is − 108°. It is to be regarded as malonic anhydride, since it is formed by the removal of two molecules of water from malonic acid and because it recombines with water, forming malonic acid :[9]



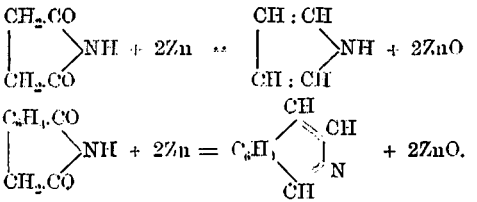
This oxide of carbon can also be prepared by the action of zinc turnings upon di-brom-malonyl bromide :

Zinc is a valuable reducing agent in acid, alkaline, or neutral solution, and in the dry state it is used to remove oxygen from phenols and other oxygen-containing bodies. By mixing alizarin with zinc dust, and heating the mixture, Graebe and Liebermann in 1886, reduced the dye-substance to its parent hydrocarbon, anthracene.

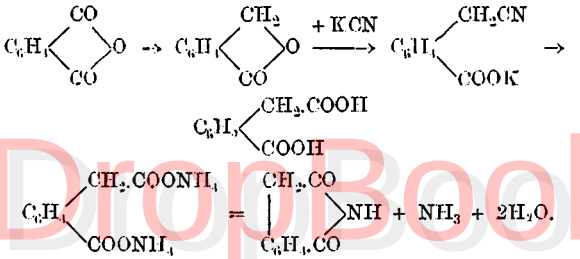
In effecting the reduction of oxygen compounds by this method, zinc dust is mixed with the substance to be reduced, and the mixture is then heated in a combustion tube. The reduction is often facilitated by passing a stream of hydrogen or carbon dioxide through the heated mixture :

$$C_6H_5OH + Zn = C_6H_6 + ZnO\,;\; C_{10}H_7OH + Zn = C_{10}H_8 + ZnO.$$

By this method succinimide can be converted to pyrrol, and homo-phthalimide to isoquinoline :



Homophthalimide itself is produced by reducing phthalic anhydride and then hydrolising the cyano-addition product; the ammonium salt of the acid formed is then heated:



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Zinc Chloride.

This substance is used to effect condensation by the elimination of water, ammonia, or hydrogen chloride.

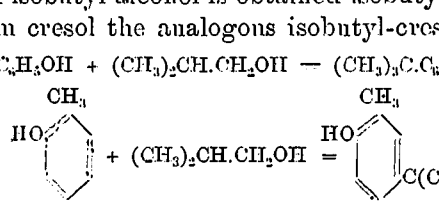
It was used by Groves in 1874, to prepare ethyl chloride by the interaction of ethyl alcohol and hydrogen chloride:[10]

$$C_2H_5OH + HCl = C_2H_5Cl + H_2O.$$

Illustrative of the power of zinc chloride to eliminate the elements of water, is the fact that many of the higher primary alcohols when heated with this reagent, become converted into olefine hydrocarbons.

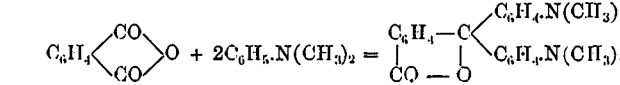
Homologues of the phenols can be prepared by heating a mixture of the phenol with a primary alcohol and zinc chloride at 200°; thus, from phenol and isobutyl alcohol is obtained isobutyl-phenol, while from cresol the analogous isobutyl-cresol results :[11]

$$C_6H_5OH + (CH_3)_2CH.CH_2OH = (CH_3)_3C.C_6H_4.OH + H_2O.$$

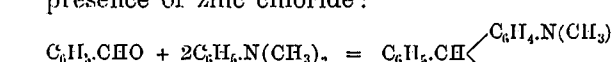


Alkyl ethers of the phenols are formed simultaneously.

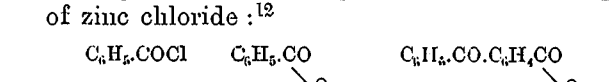
The production of phthaleins by zinc chloride is exemplified by the condensation of phthalic anhydride and dimethyl-aniline :



The leuco-base of *malachite green* is formed by condensing benzaldehyde with dimethyl-aniline in the presence of zinc chloride :

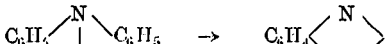


Acid chlorides condense with acid anydrides, hydrogen chloride being eliminated in the presence of zinc chloride :[12]



Acridine and its homologues are formed by heating

the acidyl derivatives of diphenylamine with zinc chloride :[13]



The method of Groves for preparing alkyl chlorides has been improved by Dehn and Davis, who recommend the use of phosphorus trichloride instead of hydrogen chloride.

The reaction is represented by the following equation :[14]

$$PCl_3 + ZnCl_2 + 3C_3H_7OH = 3C_3H_7Cl + 2HCl + ZnHPO_3.$$

While the maximum yield by Groves' method, using hydrogen chloride, was 28 per cent., they obtained by the above modification a yield of 90 per cent. of propyl chloride, and with isobutyl and isoamyl chlorides the yields were 60 and 70 per cent. respectively.

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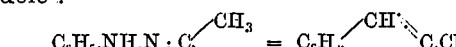
Many condensations are brought about with the elimination of ammonia, by zinc chloride.

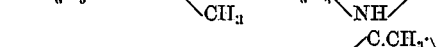
Naphthylamine and methyl alcohol yield naphthyl-methyl-ether :

$$C_{10}H_7.NH_2 + CH_3OH = C_{10}H_7.O.CH_3 + NH_3.$$

Phenyl-hydrazones of aldehydes and ketones lose ammonia and form indol derivatives.[15]

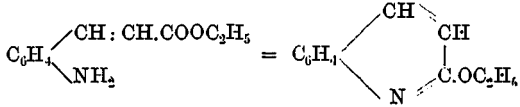
Acetone phenyl-hydrazone gives α-methyl-indole, while the hydrazone of propaldehyde gives β-methyl-indole :





Zinc chloride may be used to assist the introduction of acetyl groups by means of acetic anhydride.[16]

A saturated alcoholic solution of the chloride may sometimes be used instead of the solid itself. For example, by warming o-amino-cinnamic ester in an alcoholic solution saturated with the chloride, water is eliminated and α-ethoxy-quinoline results :[17]



Metallic zinc may be used as an oxidising catalyst. When the vapour of alcohol, mixed with air, is passed through a tube containing heated zinc, a yield of aldehyde amounting to 80 per cent. may be obtained.

Mercury and Mercury Compounds.

The use of mercury and its compounds is confined to the substitution of halogens and to oxidation.

The aluminium-mercury couple (prepared by immersing aluminium foil in mercuric chloride solution) is a halogen carrier of some value, and is used to facilitate substitution in the aromatic series of compounds, by chlorine and bromine.

For this purpose the hydrocarbon or the body into which it is desired to introduce bromine is placed in a flask and a few pieces of the couple added ; the bromine is then added slowly and the substitution is accompanied by a vigorous reaction.[18]

Mercuric oxide is utilised when iodine is to be

introduced; the easily reducible oxide forms mercuric iodide with the liberated hydrogen iodide which it is essential to remove from the sphere of action.

The following are examples of this method:

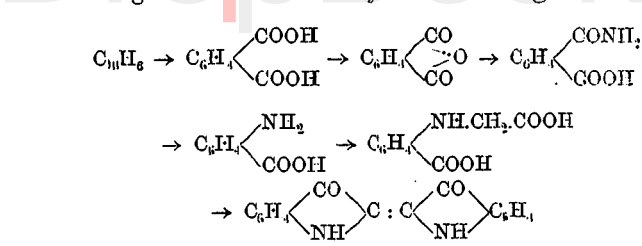
Phenol is converted to iodo- and di-iodo-phenol by adding gradually, iodine and mercuric oxide to an alcoholic solution of phenol and agitating:[19]

$$2C_6H_5OH + HgO + 2I_2 = 2C_6H_4(OH)I + HgI_2 + H_2O$$
$$2C_6H_5OH + 2HgO + 4I_2 = 2C_6H_3(OH)I_2 + 2HgI_2 + 2H_2O.$$

Iodo-durene is obtained by adding iodine and mercuric oxide to durene dissolved in petroleum ether, and allowing the mixture to stand some time.[20]

As an oxidant, mercury may be used in the presence of sulphuric acid. One of the most important examples of this is the oxidation of naphthalene to phthalic acid, used on the large scale in the first stage of the process for preparing indigo from the hydrocarbon.

The phthalic acid is next converted into anthranilic acid, and this is condensed with chloracetic acid; the stages are indicated by the following formulæ:



The phenyl-glycine-carbonic acid is fused with caustic soda and the aqueous extract from the fused mass oxidised by air.

The use of mercuric oxide as a mild oxidant is shown in the following examples.

Salts of phenyl-hydrazine are oxidised to the corresponding diazo-compounds:

$$(C_6H_5.NH.NH_2)_2\,H_2SO_4 + 2O_2 = (C_6H_5.N:N)_2\,SO_4 + 4H_2O.$$

Di-ethyl-hydrazine is oxidised to tetra-ethyl-tetrazone:

$$2(C_2H_5)_2N.NH_2 + O_2 = (C_2H_5)_2\,N.N:N.N(C_2H_5)_2 + 2H_2O.$$

This action differs from that of Fehling's solution, which in the first case gives benzene and in the second case diethylamine:

$$2C_6H_5.NH.NH_2 + O_2 = 2C_6H_6 + 2N_2 + 2H_2O$$
$$4(C_2H_5)_2N.NH_2 + O_2 = 4(C_2H_5)_2NH + 2N_2 + 2H_2O.$$

The addition of the elements of water to various acetylenes takes place in the presence of mercuric bromide and other mercury salts.[21]

Acetylene is converted to acetaldehyde, allylene to acetone, and valerylene also to a ketone:

$$C_2H_2 + H_2O = CH_3.CHO;\quad CH_3.C:CH + H_2O = CH_3.CO.CH_3.$$

BIBLIOGRAPHY.

1 Bull. Soc. Chim., 1911 (iv), 9 (i–xxv).
2 Compt. rend., 1907, **145**, 73.
3 Compt. rend., 1909, **148**, 489.
4 Compt. rend., 1912, **154**, 596.
5 Trans., 1897, **71**, 457.
6 Ber., 1902, **35**, 2140; J. prakt. Chem., 1908 (ii), **78**, 97.
7 Ann., 1888, **247**, 1807.
8 Ber., 1908, **41**, 594, 906.
9 Ber., 1906, **39**, 689.
10 Ann., 1874, **174**, 372.
11 Ber., 1881, **14**, 1842; Ber., 1894, **27**, 1614.

[12] Ber., 1881, **14**, 648.
[13] Ber., 1884, **17**, 101.
[14] J. Amer. Chem. Soc., 1907, **29**, 1328.
[15] Ber., 1886, **19**, 1563.
[16] Ber., 1889, **22**, 1465.
[17] Ber., 1882, **15**, 2103.
[18] Trans., 1899, **75**, 893.
[19] Chem. Centr., 1870, 63.
[20] Ber., 1892, **25**, 1522.
[21] Ber., 1881, **14**, 1542; Ber., 1884, **17**, 28.

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CHAPTER V

ALUMINIUM. TIN. LEAD. ANTIMONY. VANADIUM

The use of aluminium chloride for bringing about condensation by the elimination of hydrogen chloride was first made known by Friedel and Crafts in 1877, who applied it to the preparation of benzene hydrocarbons by the treatment of benzene with alkyl chlorides, in the presence of anhydrous aluminium chloride:

$$C_6H_6 + CH_3Cl = C_6H_5.CH_3 + HCl$$
$$C_6H_6 + C_2H_5Br = C_6H_5.C_2H_5 + HBr.$$

Its use has been greatly extended, and aromatic ketones may be prepared by using acid chlorides and benzene hydrocarbons. For example, benzene with acetyl chloride gives acetophenone, while benzene with carbonyl chloride gives benzophenone:

$$C_6H_6 + CH_3.COCl = C_6H_5.CO.CH_3 + HCl$$
$$2C_6H_6 + COCl_2 = C_6H_5.CO.C_6H_5 + 2HCl.$$

Aluminium chloride condensations are effected by mixing the reagents in a suitable solvent (carbon

bisulphide, petroleum ether, etc.) and gradually adding powdered, dry, and freshly prepared aluminium chloride. If desired the procedure may be altered by placing the whole amount of aluminium chloride in the solvent and then adding the reacting substances gradually.

The reaction, which is vigorous, is completed by heating the mixture on the water-bath, and then pouring the contents into cold water previous to extracting the end-product with benzene, ether or other suitable solvent.

Acids can be prepared by using carbonyl chloride or carbamic chloride; in the former case an acid chloride is obtained in the first instance, and in the latter case an amide:[1]

$$C_6H_6 + COCl_2 = C_6H_5.COCl + HCl$$
$$C_6H_6 + ClCONH_2 = C_6H_5.CO.NH_2 + HCl.$$

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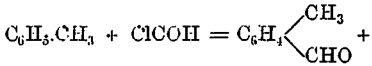
Aldehydes of phenols and of phenol-ethers can be obtained by passing gaseous hydrogen chloride and hydrogen cyanide into the phenolic substance, mixed with aluminium chloride:[2]

$$C_6H_5.O.CH_3 + ClCH:NH = C_6H_4\begin{cases}OCH_3\\CH:NH\end{cases} + HCl.$$

The intermediate imino-compound is acidified and distilled with steam:

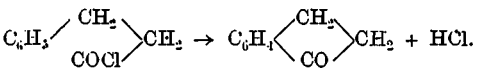
$$C_6H_4\begin{cases}OCH_3\\CH:NH\end{cases} + H_2O = C_6H_4\begin{cases}OCH_3\\CHO\end{cases} + NH_3.$$

Aldehydes can be formed by acting upon aromatic hydrocarbons with a gaseous mixture of carbon monoxide and hydrogen chloride:[3]

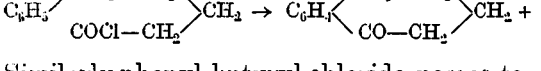


The following are examples of internal condensation brought about by $AlCl_3$:[4]

Phenyl propionyl chloride → hydrindone :

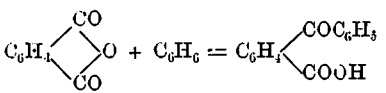


Phenyl valeryl chloride → pheno-keto-heptamethylene :

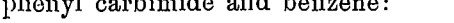


Similarly phenyl-butyryl chloride passes to α-keto-tetrahydro-naphthalene.

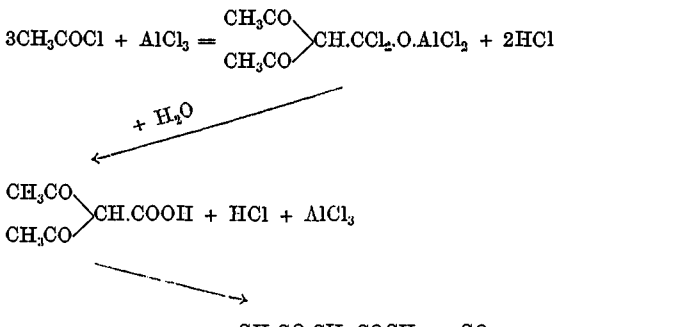
Sometimes direct combination of two molecules results without any elimination taking place, as for example, in the union of phthalic anhydride and benzene to form o-benzoyl benzoic acid :[5]



Another example is the formation of benzanilide from phenyl carbimide and benzene:



β-Diketones (1 : 3-diketones) may be obtained from acid chlorides, and here again, an intermediate addition compound appears to be formed and then decomposed by treatment with water. The formation of acetyl acetone from acetyl chloride will serve to illustrate this type of synthesis :



Benzene is converted into benzene sulphinic acid by sulphur dioxide, in the presence of anhydrous aluminium chloride, while oxygen will bring about the formation of phenol:[6]

$$C_6H_6 + SO_2 = C_6H_5.SO_2H$$
$$2C_6H_6 + O_2 = 2C_6H_5OH.$$

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When substances containing hydroxyl groups are used with aluminium chloride, it is necessary to protect these groups from attack by the metallic chloride and this is accomplished by esterifying them. For example di-benzoyl-quinol is prepared by the action of benzoyl chloride upon quinol dibenzoate and subsequent hydrolysis of the product:

$$C_6H_4(O.CO.C_6H_5)_2 + 2C_6H_5.COCl = (C_6H_5CO)_2C_6H_2(O.CO.C_6H_5)_2 + 2HCl.$$
$$(C_6H_5CO)_2C_6H_2(O.CO.C_6H_5)_2 + 2H_2O = (C_6H_5CO)_2C_6H_2(OH)_2 + 2C_6H_5.COOH.$$

The function of aluminium chloride in these various condensations appears to be catalytic.[7]

Sometimes relatively small quantities of the chloride are sufficient to complete the reactions and

at other times larger quantities are necessary; complex compounds are generally formed and thus the chloride is removed from the sphere of action. Anhydrous ferric chloride, which brings about the same kind of condensation, does not exhibit the same tendency to form complex intermediate compounds and therefore acts as a catalyst.

The following are examples of the complex intermediate compounds which have been isolated:[8]

$Al_2Cl_6.C_6H_6$; $Al_2Cl_6.C_6H_3(CH_3)_3.6C_6H_6$; $Al_2Cl_6.C_3H_{16}.6C_6H_6$.

Compounds of oxygen-containing bodies have also been isolated: With ether $C_4H_{10}O.AlCl_3$; with anisole $C_7H_8O.AlCl_3$; with ethyl benzoate $C_9H_{10}O_2.AlCl_3$. All of these are crystalline solids.

A study of the reaction between anisole and benzyl chloride indicates that the change is unimolecular and that the chloride of aluminium acts as a catalyst, since the velocity of reaction is proportional to its concentration.[9]

The formation of aromatic ketones has been explained as proceeding in the following steps:[10]

$$R.COCl + AlCl_3 = R.COCl.AlCl_3$$
$$R.COCl.AlCl_3 + HR' = R.CO.R'.AlCl_3 + HCl$$
$$R.CO.R'.AlCl_3 + nH_2O = R.CO.R' + AlCl_3.nH_2O.$$

Anhydrous zinc chloride as well as ferric chloride can often be used instead of aluminium chloride in these condensations.

It is interesting that the reverse reaction can be accomplished in the case of the alkylation of benzene. All the hydrogen atoms of the hydrocarbon can be replaced by methyl groups, and conversely hexamethyl-benzene can be converted into benzene.[11]

The alkyl groups can also be made to pass from one hydrocarbon to another, toluene in the presence of aluminium chloride yielding both benzene and *meta*- and *para*-xylene.

The fact that small quantities of the aluminium-mercury couple can bring about similar condensations, indicates that the chloride acts as a catalyst; the formation of diphenyl-methane from benzyl chloride and benzene is an example of this.[12]

Inorganic radicles may be condensed with hydrocarbons as in the formation of antimony triphenyl and dimethyl-amino-phenyl-phosphine-dichloride :[13]

$$SbCl_3 + 3C_6H_6 = Sb(C_6H_5)_3 + 3HCl$$
$$PCl_3 + C_6H_5.N(CH_3)_2 = PCl_2.C_6H_4.N(CH_3)_2 + HCl.$$

Aluminium trichloride can be used for hydrolysing the alkyl ethers of phenol and its derivatives :[14]

$$C_6H_5.O.CH_3 + HCl = C_6H_5.OH + CH_3Cl$$

$$C_6H_4\begin{matrix}NO_2\\OCH_3\end{matrix} + HCl = C_6H_4\begin{matrix}NO_2\\OH\end{matrix} + CH_3Cl$$

Tin and Lead.

Both metals form compounds with organic radicles, in which the metals themselves are tetravalent.

These compounds are prepared by treating the sodium alloy of the metal with the required halogen compound, and in the case of tin two other methods are available, namely, the treatment of tin tetrachloride with sodium in the presence of the halogen organic compound, and the action of organo-magnesium compounds upon tin tetrachloride.

These reactions may be represented by the following equations (X represents Cl, Br or I) :

$$Sn + 4Na + 4RX = SnR_4 + 4NaX$$
$$SnCl_4 + 8Na + 4RX = SnR_4 + 4NaCl + 4NaX$$
$$SnCl_4 + 2MgRX = SnR_2Cl_2 + MgX_2 + MgCl_2.$$

By the action of iodine upon the tetra-alkyl compounds one or more alkyl radicles can be replaced:

$$PbR_4 + I_2 = PbR_3I + RI.$$

Compounds of the type PbR_3I and SnR_3I are converted into the corresponding hydroxides by treatment with the hydroxides of silver or sodium:

$$PbR_3I + AgOH = PbR_3OH + AgI.$$

The stannonium and plumbonium hydroxides are strongly basic crystalline substances which form salts with acids.

Optically active tin compounds have been prepared by combining the metal with four different groups and then resolving the racemic compound produced. The following scheme will indicate the method adopted by Pope and Peachy in separating active methyl-ethyl-propyl tin iodide:[15]

$$2Sn(CH_3)_3I + Zn(C_2H_5)_2 = 2Sn(CH_3)_3(C_2H_5) + ZnI_2$$
$$Sn(CH_3)_3(C_2H_5) + I_2 = Sn(CH_3)_2(C_2H_5)I + CH_3I$$
$$2Sn(CH_3)_2(C_2H_5)I + Zn(C_3H_7)_2 = 2Sn(CH_3)_2(C_2H_5)(C_3H_7) + ZnI_2$$
$$Sn(CH_3)_2(C_2H_5)(C_3H_7) + I_2 = Sn(CH_3)(C_2H_5)(C_3H_7)I + CH_3I$$

(Faint yellow oil, b.p. 270°.)

Resolution was effected by treatment with the silver salt of d-camphor-sulphonic acid and subsequent decomposition of the camphor-sulphonate formed, by means of potassium iodide:

$$Sn(CH_3)(C_2H_5)(C_3H_7)I + C_{10}H_{15}OSO_3Ag = Sn(CH_3)(C_2H_5)(C_3H_7)SO_3OC_{10}H_{15} + AgI$$
$$Sn(CH_3)(C_2H_5)(C_3H_7)SO_3OC_{10}H_{15} + KI = Sn(CH_3)(C_2H_5)(C_3H_7)I + C_{10}H_{15}OSO_3K$$

Tin is used as a reducing agent in acid or alkaline solution, and after reduction the metal may be separated from the solution as sulphide by hydrogen sulphide, or if the reduced compound be a base, caustic soda may be added in excess and the base then extracted by some suitable solvent.

When using stannous chloride and hydrochloric acid for reduction, the usual proportions are 40 parts $SnCl_2$ and 100 parts HCl (1·17). This mixture may be used in alcoholic solution since stannous chloride is soluble in alcohol.[16]

Alkaline stannous chloride is largely used in preparing azo-compounds and particularly for transforming diazo-compounds into hydrocarbons :[17]

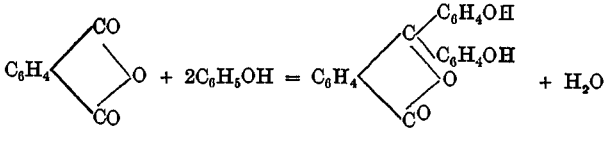
$$C_6H_5N:N.OH + H_2 = C_6H_6 + N_2 + H_2O$$

The entire reaction may be represented thus :

$$C_6H_5N:NCl + SnCl_2 + H_2O = C_6H_6 + N_2 + SnOCl_2 + HCl$$

Tin tetrachloride is very efficient in bringing about the formation of phthaleins ; for this purpose the chloride is heated with the reacting substances to about 120°.

The formation of phenol-phthalein and of salicylphenol will serve to illustrate this method :[18]



$$HO.C_6H_4.COOH + C_6H_5OH = HO.C_6H_4.CO.C_6H_4.OH + H_2O$$

The separation of organic acids by means of the lead salt which is subsequently decomposed by

hydrogen sulphide, is a method much used, and may be illustrated by reference to formic acid :

$$(HCOO)_2Pb + H_2S = PbS + 2H.COOH$$

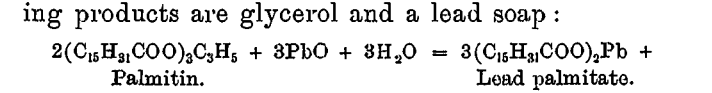
Lead monoxide, like silver oxide, may be used in the presence of water, for hydrolysis. Fats, for example, are saponified (hydrolysed) by boiling them with water containing PbO in suspension ; the resulting products are glycerol and a lead soap :

$$\underset{\text{Palmitin.}}{2(C_{15}H_{31}COO)_3C_3H_5} + 3PbO + 3H_2O = \underset{\text{Lead palmitate.}}{3(C_{15}H_{31}COO)_2Pb} + \underset{\text{Glycerol.}}{2C_3H_5(OH)_3}$$

Lead monoxide is also used as an oxidant, generally by mixing it with the compound to be oxidised and heating, or passing the vapour of the compound over heated lead oxide.

By this method benzil is oxidised to benzophenone, acenaphthene to acenaphthylene, and o-aminodiphenyl-methane is converted into acridine :[19]

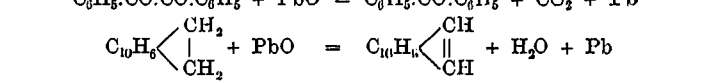
$$C_6H_5.CO.CO.C_6H_5 + PbO = C_6H_5.CO.C_6H_5 + CO_2 + Pb$$



$$C_{10}H_6\langle \overset{CH_2}{\underset{CH_2}{|}} + PbO = C_{10}H_6\langle \overset{CH}{\underset{CH}{\|}} + H_2O + Pb$$

$$C_6H_4\langle \overset{CH_2}{NH_2} \rangle C_6H_5 + 2PbO = C_6H_4\langle \overset{CH}{\underset{N}{|}} \rangle C_6H_4 + 2H_2O + 2Pb$$

Lead peroxide is used for oxidising leuco-bodies. For example, leuco-malachite green (obtained by condensing benzaldehyde with dimethyl-aniline) is converted to the base of malachite green by heating with PbO_2 :



$$C_6H_5.CH\langle \overset{C_6H_4.N(CH_3)_2}{C_6H_4.N(CH_3)_2} \rightarrow C_6H_5.C(OH)\langle \overset{C_6H_4.N(CH_3)_2}{C_6H_4.N(CH_3)_2}$$

The peroxide is utilised on the large scale for this purpose. [Germ. Patent 50782.]

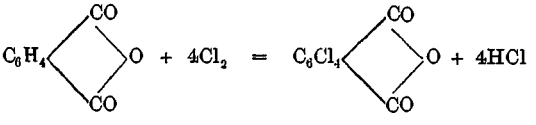
Antimony.

The chief use of antimony and its chlorides is for accelerating the chlorination of organic compounds. Chlorination is also accelerated by the chlorides of iron, aluminium, molybdenum or thallium, and the metals themselves may be used.

Just as the trichloride and pentachloride of antimony are suitable, so also are the two chlorides of molybdenum, $MoCl_3$ and $MoCl_5$, and the two chlorides of thallium, $TlCl$ and $TlCl_3$.[20]

Nitrobenzene is converted into m-chlor-nitrobenzene by chlorine in the presence of antimony trichloride.[21]

According to the German Patent 32564, phthalic anhydride is converted into the tetra-chlor-derivative by passing chlorine into a mixture of the anhydrido and antimony pentachloride heated to a temperature of 200°:



Antimony trichloride is used to facilitate pyro-condensations such as that of dinaphthyl from naphthalene. Only a small quantity of the product is obtained by passing naphthalene alone through a red-hot tube, but the yield is very much improved by mixing the vapour of antimony trichloride with the vaporised hydrocarbon:

$$6C_{10}H_8 + 2SbCl_3 = 2Sb + 6HCl + 3C_{10}H_7.C_{10}H_7$$

The vapour of stannic chloride appears to be still more efficient in this type of condensation. By its means a good yield of diphenyl is obtained from benzene.

VANADIUM PENTOXIDE has received limited application as an oxygen carrier. Its presence accelerates the oxidation of ethyl alcohol to aldehyde and acetic acid, when effected by air or by oxygen.

The oxidation of cane-sugar to oxalic acid by concentrated nitric acid is facilitated by the presence of a small quantity of vanadium pentoxide.[22]

BIBLIOGRAPHY.

[1] Ann., 1888, **244**, 50.
[2] Ann., 1906, **347**, 347; Ann., 1907, **357**, 320.
[3] Ber., 1897, **30**, 1622.
[4] Trans., 1894, **65**, 484; 1899, **75**, 144; 1901, **79**, 602.
[5] J. prakt. Chem., 1890, **149**, 147, 301.
[6] Ann. Ch. Phys. (6), **14**, 433.
[7] Trans., 1903, **83**, 1470.
[8] Compt. rend., 1903, **136**, 1065; Trans., 1904, **85**, 1106.
[9] Zeit. phys. Chem., 1904, **48**, 430.
[10] Rec. Trav. Chim., 1900, **19**, 19.
[11] Ber., 1885, **18**, 339, 657.
[12] Trans., 1895, **67**, 826.
[13] Ber., 1888, **21**, 1497.
[14] Ber., 1892, **25**, 3531.
[15] Proc., **16**, 42, 116.
[16] Ann., 1891, **264**, 131; Ber., 1882, **15**, 1422.
[17] Ber., 1885, **18**, 2912.
[18] Ann., 1880, **202**, 68; Ber., 1883, **16**, 2298.
[19] Ber., 1883, **16**, 502; Ber., 1893, **26**, 3085.
[20] Ann., 1884, **225**, 199.
[21] Ann., 1876, **182**, 102.
[22] J. prakt. Chem., 1907, **75**, 146.

CHAPTER VI

IRON. NICKEL. PLATINUM. PALLADIUM

These metals have all been used as catalysts, particularly in oxidation and reduction processes, and in this connection the value of nickel and platinum is well known.

Certain iron compounds have been used for reduction. Ferrous sulphate in aqueous solution, with ammonia, baryta, or sodium hydroxide, may be used for reducing, as also may ferrous potassium oxalate in neutral, alkaline, or weakly acid solution.

The following are examples of the reduction of nitro-compounds by ferrous sulphate: nitro-phenyl propiolic acid[1] and nitro-dichlor-benzaldehyde[2]; the method has been used to reduce several nitro-acids to the corresponding amino-acids.[3]

Ferrous potassium oxalate can be utilised in these cases with good results.[4]

The value of iron and of ferric chloride as halogen carriers is well known. Ferric chloride or ferric hydroxide may be used for oxidising purposes, the oxidant being in each case reduced to the ferrous condition.

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The oxidation of ethyl indoxylate to ethyl indoxanthinate[5] and of naphthol to dinaphthol[6] may be accomplished by ferric chloride :

$$2C_{10}H_7OH + 2FeCl_3 = C_{20}H_{12}(OH)_2 + 2HCl + 2FeCl_2$$

Ferric hydroxide is sometimes used for oxidising leuco-bases.[7]

The oxidising action of hydrogen peroxide in the presence of ferrous sulphate, was first used by Fenton and applied by him in the conversion of the polyhydric alcohols to the corresponding aldehydes.

In the first instance, the reagent was used to prepare di-hydroxy-maleic acid from tartaric acid :

$$2\begin{vmatrix} CH(OH).COOH \\ CH(OH).COOH \end{vmatrix} + O_2 = 2\begin{Vmatrix} C(OH).COOH \\ C(OH).COOH \end{Vmatrix} + 2H_2O$$

Glycerol, erythrite and mannitol can be converted to the corresponding aldoses by this oxidant : [8]

The first indication of the value of reduced nickel for accelerating the reduction of organic compounds by hydrogen, was obtained by Sabatier and Senderens in 1897, when studying the compounds obtained by passing acetylene or ethylene over heated reduced nickel. It was subsequently shown that many organic substances could be reduced in this manner, the chief factors which determined the success of the reaction being, the temperature at which the nickel was first prepared from the oxide by hydrogen, and the temperature at which the mixture of the substance and hydrogen was allowed to pass over the metallic nickel.

Generally, the catalyst (nickel) is prepared by heating pumice, impregnated with nickel oxide, in a

current of dry hydrogen at about 300°. When reduction is complete the temperature is allowed to fall to between 160° and 200°, and the mixture of the substance to be reduced, with hydrogen, is passed through the reduced nickel.

The following is a brief summary of the results hitherto obtained by this method, and a collection of references to the original papers will be found at the end of the chapter. It will be seen that although nickel is the metal most used and the one which generally yields the best results, yet other metals, namely, copper, cobalt, iron and platinum, have been utilised.

In 1897 it was found that by passing ethylene over reduced nickel at about 325°, a gaseous mixture was obtained consisting of 10 vols. of hydrogen, 60 vols. of ethane and 30 vols. of methane. At higher temperatures the volume of ethane was diminished, and the nickel was found to be most active when the nickel oxide was reduced at 300°. A mixture of ethylene and hydrogen at a temperature of 150° gave a quantitative yield of ethane.

In 1899 and during subsequent investigations, it was shown that when acetylene and hydrogen are passed over reduced nickel at ordinary temperatures the gases combine, a rise in temperature takes place spontaneously, and ethane is the chief product, but the composition of the product depends upon the temperature, the proportion of acetylene to hydrogen, and the velocity of the gas current. Olefines, paraffins and benzene are found in the product and the liquid constituents increase with rise of temperature, while

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a diminution of hydrogen also favours the formation of liquid hydrocarbons, especially benzene compounds.

Metallic iron, copper and cobalt behave in a similar way, and the formation of liquid hydrocarbons supports the idea that petroleum may have been formed naturally, by the gases evolved from the action of water upon carbides of the alkalis and alkaline earths, passing through layers of heated metals in the earth's interior.

The metals copper, iron and cobalt produce the following changes in mixtures of acetylene and hydrogen on the one hand, and mixtures of ethylene and hydrogen on the other hand.

If acetylene be passed over copper at 180–250°, a mixture of hydrogen, unchanged acetylene, and volatile hydrocarbons results; the copper swells up, owing to a deposit of yellowish highly condensed hydrocarbon of composition $(C_7H_6)_n$ which has been named *cuprene*. If the acetylene be first mixed with excess of hydrogen and the temperature 200°, the mixture resulting, contains 3 per cent. of olefine (ethylene) and 18 per cent. of ethane; a more compact form of copper at 170° causes the olefine content to increase ninefold while the ethane is reduced in quantity. If the mixture contains half its volume of acetylene and the reaction proceeds at 150° the amount of ethylene in the product is still further increased and the ethane decreased.

Reduced iron at ordinary temperatures does not affect a mixture of acetylene and hydrogen, but above 180° ethane, ethylene (and higher olefines),

and a small amount of benzene hydrocarbons result.

Reduced cobalt accelerates the reduction of acetylene to ethane by hydrogen above 180°, and some liquid paraffins result at the same time. Evidently these three metals bring about different results under similar conditions.

While copper favours ethylene formation, iron and cobalt, when a sufficently high temperature is reached, favour ethane formation accompanied in one case by benzene hydrocarbons and in the other case by liquid paraffins.

As regards mixtures of ethylene and hydrogen, the reaction, $C_2H_4 + H_2 = C_2H_6$, is not induced by copper below 180°, but between 180–300° this is the main reaction. Metallic iron has no effect on the mixture at ordinary temperatures, and when heated to 180° the reaction soon ceases owing to the metal becoming carburised.

Reduced cobalt induces the reaction, $C_2H_4 + H_2 = C_2H_6$, at first and the metal becomes spontaneously heated, but it soon becomes carburised and inactive. If heated to 100°–150° the reaction proceeds, yielding ethane mixed with unchanged ethylene and hydrogen together with traces of higher acetylenes. At 300° much unchanged ethylene and hydrogen are found with ethane, together with small amounts of methane and liquid hydrocarbons; the cobalt still becomes carburised and its activity declines.

The reaction between ethylene and hydrogen is only temporary in the presence of platinum black at ordinary temperatures, but at 100–120° slow com-

bination takes place, and at 185° the yield of ethane is almost quantitative. Spongy platinum behaves in a similar manner at 180°.

Acetylene with excess of hydrogen, in the presence of platinum black at ordinary temperatures gives only ethane, but if acetylene is in excess then ethylene is also formed, while at 180° some liquid hydrocarbons also result.

The passage of acetylene alone, over the metals nickel, platinum, cobalt and iron gives the following results.

A rapid current of acetylene when passed over reduced nickel causes intumescence, and this is apparently due to occluded hydrogen in the metal, because when displaced by a stream of nitrogen gas no reaction is observed below 180°. At higher temperatures no intumescence is observed if the acetylene current be sufficiently slow, and the products are hydrogen, ethane, ethylene and liquid hydrocarbons containing benzene with higher olefines. A rapid stream of gas gives rise to intumescence, and the issuing gas is made up of hydrogen 51·4 per cent., ethane 36·3 per cent., ethylene 2 per cent., benzene and homologues 10·3 per cent.; at the same time a liquid condenses which contains unsaturated hydrocarbons.

Finely divided platinum induces no effect with acetylene at ordinary temperatures, but above 150° intumescence is observed, and the gas is partly decomposed into carbon, ethylene, benzene, ethane, and hydrogen, the last three in small quantity.

Cobalt free from nickel has no action upon acety-

lene at ordinary temperatures, but above 200° the gas is almost completely decomposed into hydrogen, ethane and carbon while small quantities of benzene and its homologues are formed.

Iron behaves similarly but much less ethane results, while olefines and benzene accompany the gases.

Ethylene is not affected by finely divided platinum or copper below 400°, but cobalt above 300°, partly decomposes the gas into ethane, methane, hydrogen and carbon, no acetylene being formed. Iron above 350° has less action, but decomposes some of the gas into ethane, hydrogen and carbon.

The following are some of the results obtained by reducing aromatic substances in this manner:

Benzene and its homologues are reduced by hydrogen in the presence of nickel at 180–200° yielding the corresponding cyclohexanes. If the side-chain be long, then a certain amount of disruption accompanies the reduction, and lower homologues are produced as well as the normal cyclohexane. At a higher temperature, decomposition of the reduced products may occur; cyclohexane itself, for example, is decomposed if the temperature is 300°, into methane and carbon. The hydrogenation of benzene seems peculiar to nickel, since cobalt and platinum black have only a transitory effect, while spongy platinum, iron and copper are quite inert.

Limonene, sylvestrene and terpinene are all reduced to 1-methyl-4-isopropyl-cyclohexane by this method, naphthalene gives tetrahydro-naphthalene, and acenaphthene behaves similarly.

Nitrobenzene, o- and m-nitrotoluene, are all re-

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duced to the corresponding amino-compounds in the presence of copper at 300°–400°, and the reducing action of platinum black is similar. Reduced nickel acts more vigorously and reduction takes place normally at 200°, but at 250° the products obtained from nitrobenzene are benzene, cyclohexane and ammonia, as well as aniline, while at 300° benzene is the chief product.

Reduced iron and cobalt act in a similar manner to nickel when heated to 450°–500°.

Reduced copper does not effect hydrogenation in hydrocarbons unless at least one unsubstituted ($:CH_2$) group is present; styrene is reduced to ethyl benzene, and limonene $C_{10}H_{16}$ passes to $C_{10}H_{18}$, but limonene becomes still further reduced by nickel to hexahydrocymene $C_{10}H_{20}$.

Hydrogen in the presence of reduced nickel converts phenol into cyclohexanol and cyclohexane. Poly-phenols are affected similarly, while aniline and its homologues become reduced to cyclohexylamines; quinones are reduced to quinols and nitriles to amines.

The catalyst remains active in continual use, often for a month, but is poisoned by halogens or sulphur and also by the decomposition of carbonaceous matter when working at too high a temperature.

The following reactions are also important:

Carbon monoxide (1 vol.) and hydrogen (3 vols.) react in the presence of nickel at 250° to form methane and steam, $CO + 3H_2 = CH_4 + H_2O$. Carbon dioxide is also reduced at a higher temperature, $CO_2 + 4H_2 = CH_4 + 2H_2O$.

Hydrocarbons of the ethylene series up to a carbon

content of C_8, are reduced to the corresponding paraffins; below 160° the product is practically pure, but above 200° partial decomposition takes place and hydrocarbons of lower molecular weight result.

The liquid product obtained from acetylene and hydrogen at temperatures not above 200° is fluorescent, not attacked appreciably by a mixture of sulphuric and nitric acids, and presents the characteristics of American petroleum. Acetylene alone, yields a green-coloured liquid which resembles Russian petroleum.

Dehydrogenation takes place when the vapour of primary alcohols is passed over reduced copper at 250°–300° and aldehydes result, while secondary alcohols are converted by the same method into ketones.

Nickel and cobalt effect the same changes, but in too vigorous a manner generally.

Tertiary alcohols are decomposed into olefines and water by the agency of reduced nickel and copper.

For the catalytic reduction of aldehydes, nickel reduced at as low a temperature as possible is most efficient; a quantitative yield of alcohol from acetaldehyde is obtained at 140°, while the optimum temperature for reducing formaldehyde is 90° and for propaldehyde 102°–140°.

Reduced cobalt, platinum sponge, and copper are not suitable for aldehyde reduction.

The reduction of oleic acid to stearic acid by this method is of technical importance and is one example of the reduction of unsaturated aliphatic acids to the corresponding saturated acids.

Iron, nickel, zinc or lead may be used, according

to the German Patent 185932, for reducing formic acid to formaldehyde by hydrogen at 300°.

Sabatier and Maihle have studied the catalytic action of various metallic oxides upon the vapours of certain organic compounds. They find that alcohols are oxidised to aldehydes by manganous oxide and that they are dehydrated by alumina, thoria or the blue oxide of tungsten, with the formation of olefines and ethers. Those changes are explained in the case of thoria by the following equations:

$$ThO_2 + 2C_nH_{2n+1}.OH = ThO(OC_nH_{2n+1})_2 + H_2O$$
Below 300° $$ThO(OC_nH_{2n+1})_2 = ThO_2 + (C_nH_{2n+1})_2O$$
Above 300° $$ThO(OC_nH_{2n+1})_2 = ThO_2 + H_2O + 2C_nH_{2n}.$$

The results obtained by passing the vapour of primary alcohols over various heated metallic oxides have been summarised, and the oxides used have been arranged in four classes as follows:[9]

(1) The oxidation is limited to the formation of aldehyde and water; the metallic oxide used has no effect upon the aldehyde and the metal or lower oxide which results has no catalytic power. To this class belong Sb_2O_3 and Bi_2O_3.

(2) The aldehyde formed may be partly oxidised either to the corresponding acid, or with the formation of carbon dioxide and water. Mercuric oxide at 150° oxidises alcohol to acetaldehyde with the simultaneous formation of carbon dioxide, but no acetic acid is produced.

Manganese dioxide at 200° oxidises alcohol to aldehyde and is itself reduced to Mn_2O_3; at 250° the Mn_2O_3 brings about further oxidation and the products are acetaldehyde, carbon dioxide, and acetic acid.

(3) The oxides catalytically dehydrate the alcohol, and ethylene is the chief result. To this class belong Fe_2O_3, Al_2O_3, and ThO_2.

(4) The largest class consists of those oxides which are reduced to the metal, or a lower oxide, capable of producing a catalytic effect which is superposed upon the initial oxidation. The oxides of nickel and cobalt, of lead (PbO_2, Pb_3O_4, PbO), of copper (CuO, Cu_2O), at 350° belong to this class; the reduced metals in these cases have a *dehydrogenating* effect upon the alcohol, and aldehyde results.

Mn_2O_3 is reduced at 350° to pale green MnO, which converts the alcohol to aldehyde by dehydrogenation.

Tungstic oxide at 350° is reduced to a blue oxide which has a dehydrating effect and ethylene results as well as aldehyde and acetic acid.

The oxides UO_3 and V_2O_5 are reduced to UO_2 and V_2O_3 respectively, aldehyde and carbon dioxide resulting. The further action of UO_2 or V_2O_3 gives aldehyde, hydrogen, ethylene and water.

Mixed ethers result when alcohols and phenols are used with thoria at 390°–420° and esterification takes place when alcohol and acid interact at 350°–400°. Esterification[10] is more complete in the presence of titanic oxide at 280°–300°. One molecule of acid is used with twelve molecules of alcohol, and in this way methyl, ethyl, propyl, butyl, and benzyl esters have been prepared from acetic, propionic and butyric acids.

In the case of formic acid it is necessary to work at 150° with titanium oxide and at 200° with thoria to avoid decomposition of the acid.

Hydrolysis is effected under similar conditions if the ester and excess of steam are passed over these catalysts.

Olefines are obtained by passing the vapour of paraffin monohalides over reduced nickel or copper, heated to 250°; the resulting products are the olefine and the haloid acid, which are prevented from recombining by passing them through potash. The chlorine derivatives decompose thus below 260°, but a higher temperature is required for bromo- and iodo-compounds.[11] The bivalent chlorides of nickel, cobalt, cadmium, iron, lead and barium produce the same effect at 300°; barium chloride is the most efficient catalyst. Chlorides of univalent metals are not able to bring about this change, and the following equations possibly represent the reaction in the case of the bivalent chlorides:

(1) $MCl_2 + C_nH_{2n+1}Cl = MCl.C_nH_{2n}Cl + HCl.$
(2) $MCl.C_nH_{2n}Cl = C_nH_{2n} + MCl_2.$

The reduction of nitriles by hydrogen in the presence of reduced nickel or copper usually gives primary, secondary and tertiary amines together with ammonia, and the changes are probably represented by the following equations:[12]

(1) $R.CN + 2H_2 = R.CH_2NH_2$
(2) $2R.CH_2NH_2 = (R.CH_2)_2NH + NH_3$
(3) $3R.CH_2NH_2 = (R.CH_2)_3N + 2NH_3.$

Aldoximes are reduced to amines by hydrogen at 180–220° in the presence of reduced nickel or copper; with benzaldoxime, however, the chief product is benzaldehyde when copper is used, and toluene when nickel is used.[13]

Primary alcohols are converted into primary, secondary and tertiary amines, by ammonia, in the presence of heated tungstic oxide or thoria.

A mixture of reduced nickel and alumina may be used to effect reduction by hydrogen and the simultaneous fission of water; thus fenchenol is converted by this method into fenchane and borneol is transformed into iso-camphane :[14]

$$C_{10}H_{17}OH \rightarrow C_{10}H_{16} \rightarrow C_{10}H_{18}.$$

PLATINUM is not only suitable for accelerating reduction processes, but is also an excellent catalyst when oxidation is effected by air or oxygen. Formaldehyde was first prepared by passing the vapour of methyl alcohol and air over a heated platinum spiral.[15]

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Later, copper gauze was found equally effective, and formaldehyde is now manufactured by passing the vapour of wood spirit mixed with air, over finely divided platinum or copper distributed over an earthenware surface. The following processes for manufacturing ammonia and nitrates or nitrites (substances essential for the synthesis of the highly complex plant and animal bodies), depend largely upon the use of platinum as a catalytic agent.

Ammonia is formed when nitric oxide and hydrogen are mixed and passed over platinum sponge at 80°. The hydrogen used may be that present in Dowson-gas or water-gas and the reaction involved is indicated by the following equation :[16]

$$2NO + 5H_2 = 2NH_3 + 2H_2O.$$

If ammonia and air be passed over red-hot finely

divided platinum (or one of the platinum metals), nitric acid is formed,[17] and nitrous acid is produced in the same way if ferric oxide at 700° be substituted for platinum.[18]

Ammonia is now made by the Badische Anilin und Sodafabrik, by passing nitrogen and hydrogen over heated platinum at a temperature of 80°, under a pressure of about thirty atmospheres. Other catalysts used in the process are manganese, uranium and osmium.

Keten has been prepared from acetic anhydride, by exposing the vapour of the anhydride to the dehydrating influence of a white-hot platinum wire :[19]

$$\begin{matrix} CH_3.CO \\ \diagdown \\ \quad O \\ \diagup \\ CH_3.CO \end{matrix} = 2CH_2{:}CO + H_2O.$$

Platinum and palladium in colloidal solution are used for effecting the *hydrogenation* of substances in aqueous or alcoholic solution. Hydrogen is passed through the solutions and it is often advantageous to work under slightly increased pressure; the colloidal metals are obtained from palladious chloride or potassium platinichloride, in the presence of gum arabic.

By this method unsaturated aldehydes and ketones are converted into the corresponding saturated compounds, while benzene, toluene and benzoic acid may be converted into cyclohexane, methyl-cyclohexane and cyclo-hexane-carboxylic acid respectively.[20]

The reduction of nitro-compounds in solution by spongy copper depends upon the precipitation of the copper from copper sulphate solution by sodium

hypophosphite and the simultaneous decomposition of water, with evolution of hydrogen.[21]

The nitro-compound is usually dissolved in alcohol, spongy copper added, and an aqueous solution of hypophosphite is gradually run into the mixture.

The presence of halogen or hydroxyl groups in the nitro-compound is no disadvantage and good yields are obtained.

BIBLIOGRAPHY.

[1] Ber., 1882, **15**, 2147.
[2] Ber., 1884, **17**, 754.
[3] Ber., 1879, **12**, 1946.
[4] Monats., 1880, **1**, 137.
[5] Ber., 1882, **15**, 775.
[6] Ber., 1888, **21**, 728.
[7] D.R.P. 19484.
[8] Trans., 1899, **75**, 1.
[9] Compt. rend., 1908, **147**, 16.
[10] Compt. rend., 1911, **152**, 358, 494, 1044.
[11] Chem. Zeit., 1906, **30**, 37.
[12] Chem. Zeit., 1906, **30**, 458.
[13] Compt. rend., 1905, **140**, 1691.
[14] Ber., 1912, **45**, 3205.
[15] Ann., 1868, **145**, 358.
[16] D.R.P., 1572876.
[17] Eng. Patent, 1903, 698.
[18] French Patent, 1903, 335229.
[19] Trans., 1907, **91**, 1941.
[20] Ber., 1912, **45**, 3579.
[21] Bull. Soc. Chim., 1910 (iv), **7**, 952.

References to the papers of Sabatier and Senderens in 'Comptes rendus de l'Académie des Sciences,' Paris.

1897, **124**, 616, 1358; 1899, **128**, 1173;
1900, **130**, 250, 1559, 1761, 1628;
1900, **131**, 40, 187, 267;

1901, **132**, 210, 566, 1254; **133**, 321;
1902, **134**, 514, 1127, 689, 1185; **135**, 87, 225;
1903, **136**, 738, 921, 983; **137**, 301, 1025;
1904, **138**, 457, 1257; 1905, **140**, 482;
1906, **142**, 1394;
1908, **146**, 457, 1193; **147**, 106;
1909, **148**, 898, 1734; 1910, **150**, 823;
1911, **152**, 358, 494, 669, 1212;

Also 'Ann. Chim. Phys.,'—

1905, **4**, 319, 433;
1909, **16**, 70.

APPENDIX I

PRACTICAL WORK: SODIUM. POTASSIUM

ETHYL BENZENE from brom-benzene and ethyl bromide.

[Ann., 1864, **131**, 304. Ann., 1869, **149**, 342.]

The brom-benzene (60 gms.) and ethyl bromide (50 gms.) are mixed in a 1-litre flask fitted with a reflux condenser, and double the volume of dry ether added.

The sodium (18 gms.), in small pieces, or in the form of wire, is added gradually, and a few drops of acetic ethyl ester may be added to accelerate the reaction.

When all the sodium has been added the mixture should stand for four or five hours (preferably over-night), and then be boiled on the water-bath for half an hour. After cooling, the liquid is decanted from the sodium bromide and the residue washed twice with dry ether. The washings are added to the original liquid, and after distilling off the ether the residual oil is fractionated. That fraction is collected which distils between 132°–135°. Yield, about 20 gms.

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ANISOLE from sodium phenate and methyl iodide.

[Ann., 1851, **78**, 226.]

Sodium (5 gms.) in small pieces is dissolved in methyl alcohol (100 c.cm.) contained in a ¼-litre flask fitted with a reflux condenser. When the sodium has all dissolved, phenol (20 gms.) and methyl iodide (40 gms.) are added, and the mixture heated on the water-bath until it gives no alkaline reaction (about three hours).

The alcohol is then distilled off and water added to the residue to precipitate the anisole, which is extracted with ether. After drying the ethereal extract over calcium chloride, the ether is distilled off and the residual oil fractionated, that fraction being collected which boils between 150°–155°. Yield, about 16 gms. of a colourless oil with ageeable odour, b.p. 154°.

BENZOIC ANHYDRIDE from sodium benzoate and benzoyl chloride.

Benzoyl chloride (10 gms.) is added to powdered sodium benzoate (10 gms.) in a small retort and the mixture is heated strongly. The distillate, which is collected in a receiver, solidifies and may be recrystallised from benzene, and the odour of benzoyl chloride may be removed from the crystals of benzoic anhydride by placing them in a desiccator over solid potassium hydroxide for a few hours.

Yield, about 12 gms. Rhombic prisms; m.p. 42°, b.p. 360°.

Hexamethylene from the dibromide.

[Trans., 1894, **65**, 599.]

The preparation of hexamethylene dibromide from $\omega\omega^1$-chloro-brom-propane, which is itself prepared from allyl chloride, is as follows:

Allyl alcohol may be converted into allyl chloride by heating with conc. hydrochloric acid in a sealed tube at 100° for several hours.

Allyl chloride is then converted to chloro-brom-propane by heating in a sealed tube with a slight excess of conc. hydrogen bromide solution at 100° for seven to eight hours. The mixture is then washed, dried and fractionated.

The boiling point of the product is 140°–142°.

Chloro-brom-propane (1 mol.) is next dissolved in a little methyl alcohol, and the calculated amount of sodium (1 atom in twelve times its weight of methyl alcohol) is added in three portions, the mixture being boiled after each addition.

As soon as the vigorous action ceases the product is cooled and mixed with twice its volume of water, the oily layer extracted with ether and the ethereal solution washed with water to remove alcohol. After drying the extract over calcium chloride it is distilled with a fractionating column: the portion boiling at 115°–118° is chlor-methoxy-propane, yield 50–60 per cent.

Chlor-methoxy-propane (20 gms.) is next dissolved in 60 c.c. of light petroleum (b.p. 50°–60°) and heated to boiling under a long reflux condenser.

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The flame is removed and small pieces of potassium added gradually, the very violent action after each addition being allowed to subside before adding another piece. The mixture soon thickens owing to the separation of potassium chloride, and when the metal is no longer acted upon the whole is boiled for half an hour, any unchanged metal being removed by alcohol.

The product is then poured into water, the oily layer separated and dried over calcium chloride before fractionating. Most of the liquid distils between 100°–150° and is unchanged chlor-methoxy-propane, while the liquid boiling above 150° is chiefly di-methoxy-hexane, which is next digested under a reflux condenser for three hours with fuming hydrobromic acid. The dark-coloured product is poured into water, the oily layer extracted with ether, and after removing the ether from the dried extract, the residue is heated in a sealed tube with hydrobromic acid for two hours at 150°–160°. The product is poured into water, extracted with ether, and the dark-coloured hexamethylene dibromide fractionated under reduced pressure (20 mm.). That portion is collected which boils between 125° and 140°.

The heavy colourless dibromide (30 gms.) is now mixed with *meta*-xylene (30 gms.), and added through a funnel drop by drop to a mixture of sodium (15 gms.) in small pieces, and 70 c.c. of *m*-xylene. The reaction is vigorous, and if a condenser be fitted to the side-tube of the reaction-flask, the resulting hexamethylene distils over between 70° and 100°; this may be refractionated over sodium and that part

collected which distils at 77°–80°. Yield about 10 gms.

Trimethylene Dicarboxylic Acid.

[Ber., 1884, **17**, 54.]

Di-sodium malonic ester is prepared by dissolving sodium (13·5 gms.) in alcohol (150 gms.) and adding malonic ester (45 gms.) gradually. Ethylene dibromide (54 gms.) is then slowly added, and the solid mass which forms is then heated under a reflux condenser to 100° for twenty hours; the mass becomes liquid soon after heating, and at the end of this time should be no longer alkaline to litmus. The excess of alcohol is next distilled over and the residue mixed with water to dissolve sodium bromide, after which it is extracted with ether and the extract dried over calcium chloride. The dried extract is now freed from ether by distillation, and the residual yellow-coloured oil fractionally distilled in a flask with a long neck and the fraction collected which distils between 195°–225°. This fraction should again be distilled and the portion boiling at 203°–210° collected.

To separate malonic ester still present and which amounts to 15 to 20 per cent. it must be converted into the higher boiling derivative, benzyl-malonic ester. For this purpose half a gram of sodium in alcohol is added to every 20 gms. of the oil collected, and to this mixture 2·5 gms. of benzyl chloride is added and the whole heated until neutral.

Water is then added and the esters extracted with

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ether, and after removing the ether the remaining oil is fractionated. Benzyl-malonic ester boils at 300°, so that the trimethylene ester may be separated by collecting the distillate which passes over at 206°–210°.

The ester is hydrolysed by boiling with alcoholic potash for three hours, and after boiling off all alcohol the residue is dissolved in water, and on acidifying with sulphuric acid the trimethylene dicarboxylic acid is extracted with ether. Crystalline solid, m.p. 140°. By heating to 200° carbon dioxide is evolved and the mono-carboxylic acid results, which is a liquid, b.p. 188°–190°.

Chloroformic Ester.

[Ber., 1885, **18**, 1177.]

Liquid carbonyl chloride is placed in a flask which is immersed in a freezing mixture. The flask is fitted with a reflux condenser through which a stream of ice-cold water circulates. The upper end of the condenser is closed by a cork through which passes a calcium chloride tube, and into which is fixed a dropping funnel. The calculated quantity of methyl alcohol is slowly added from the dropping funnel; a vigorous reaction follows the fall of each drop and hydrogen chloride is evolved and passes out through the calcium chloride tube. When the addition of alcohol produces no further action the ester is poured into water, washed with soda carb. solution, separated and dried over calcium chloride; b.p. 70°.

Carbonyl Chloride.

(Ber., 1893, **26**, 1930.)

For this purpose sulphur trioxide is allowed to act upon carbon tetrachloride. $CCl_4 + 2SO_3 = COCl_2 + S_2O_5Cl_2$.

The pyrosulphuryl chloride formed reacts with the sulphuric acid present thus: $S_2O_5Cl_2 + H_2SO_4 = SO_3 + 2ClSO_3OH$.

The carbon tetrachloride (50 gms.) is boiled on the water-bath under a reflux condenser (preferably one having three or four bulbs on the inner tube), with a side-tube fused into the top part and a dropping funnel fitted in the open end, through which 60 c.c. fuming sulphuric acid (80 per cent. SO_3) is dropped slowly. The vapours which ascend the condenser pass out through the side-tube and are washed by passing through conc. sulphuric acid (well cooled); they then pass into a receiver immersed in a freezing mixture where the carbonyl chloride collects. Washing through conc. sulphuric acid serves to remove SO_3 and $S_2O_5Cl_2$ from the vapours.

When all the fuming sulphuric acid has been added the flask may be warmed for five minutes over the flame to drive out all $COCl_2$. Weight of crude product is 25–30 gms. This may be purified by redistilling through conc. sulphuric acid, the warmth of the hand being sufficient to produce boiling, b.p. + 8°.

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Methyl Benzoate.

[Ann., Suppl. 7, 125.]

Brom-benzene (30 gms.) and chloroformic ester (20 gms.) are mixed with 1 per cent. sodium amalgam (1200 gms.) and heated for several days at 110° under a reflux condenser. The mercury is then poured off, the residue extracted with ether and the extract fractionally distilled.

B. p. of methyl benzoate is 199°.

Toluic Ethyl Ester.

This may be prepared in the same manner as methyl benzoate, using brom-toluene (34 gms.), chloroformic ethyl ester (20 gms.), and 1 per cent. sodium amalgam (1500 gms).

Acetoacetic Ester.

[Ann., 1877, **186**, 161.]

Acetic ester (200 gms.) is placed in a round flask and sodium in thin slices (20 gms.) is quickly added. After this a reflux condenser is fitted to the flask, and if the reaction becomes too vigorous the latter must be immersed in cold water. When the reaction subsides the mixture is boiled on the water-bath until no sodium remains, and after cooling, the mixture is made acid by adding 50 per cent. acetic acid (about 100 c.c.); an equal volume of saturated brine is then added to salt out any acetic ester, which collects at the top with acetoacetic ester. This layer is placed in a distilling flask and distilled over wire

gauze until the temperature reaches 100°, to remove all acetic ester. The remaining liquid is distilled under reduced pressure to avoid decomposition of the acetoacetic ester.

The boiling points under various pressures are as follows:

88° at 29 mm. . . 97° at 59 mm.
94° „ 45 „ . . 100° „ 80 „

The yield is about 35 gms., b.p. 181°.

Ethyl Acetoacetic Ethyl Ester.

[Ann., 1878, **192**, 153.]

Aceto-acetic ester (32 gms.) is added to a solution of sodium (5·5 gms.) in alcohol (70 gms.), and to this mixture is gradually added ethyl iodide (40 gms.). The mixture is then heated on the water-bath till it gives no alkaline reaction with litmus (about 2½ hours). Most of the alcohol is then distilled off, the residue is mixed with water to dissolve the sodium iodide and then extracted with ether. After drying the ethereal extract over calcium chloride, the ether is distilled off and the remaining oil fractionally distilled. Yield about 25 gms., b.p. 198°.

The yield may be improved by distilling under reduced pressure. B. p. at 140 mm. pressure is 140°, at 100 mm. 127°, at 40 mm. 106°.

Acid hydrolysis of the ester by concentrated potash.

[Ann., 1877, **190**, 276.]

The ester (20 gms.) is boiled with 22 per cent. alcoholic potash (made by dissolving 20 gms. of

potash in 90 c.c. of alcohol) for four hours under a reflux condenser. When cool, it is extracted with ether to remove any ketone formed, and then again extracted after acidifying with sulphuric acid, to remove butyric acid. After drying the extract over calcium chloride the ether is distilled off.

Yield of butyric acid about 8 gms., b.p. 163°.

Ketonic hydrolysis of the ester by dilute sulphuric acid.

$$CH_3CO.CH(C_2H_5).COOC_2H_5 + H_2O = CH_3CO.CH_2.C_2H_5 + CO_2 + C_2H_5OH.$$

The ester (20 gms.) is boiled with 200 c.c. of dilute sulphuric acid (1 part acid to 2 parts water) for three hours under a reflux condenser. The cooled mixture is then extracted with ether, and after drying the extract over calcium chloride, the ether is distilled off and the remaining oil fractionally distilled. Yield about 10 gms. B.p. of propyl-methyl-ketone is 102°.

Aceto-succinic Ethyl Ester.

A mixture of aceto-acetic ester (33 gms.) with sodium (5 gms.) dissolved in alcohol (70 gms.) is treated with mono-chlor-acetic ester (32 gms.) which is added gradually. The mixture is then boiled on the water-bath until no alkaline reaction is shown (about two hours), after which it is treated with water to dissolve sodium chloride, extracted with ether, and the ethereal extract dried over calcium chloride and distilled. Yield 12–15 gms. of a pale yellow oil, b.p. 256°.

Malonic Ester.

[Ann., 1880, **204**, 120.]

In this preparation chlor-acetic acid is converted into potassium cyanacetate, which is then hydrolysed and esterified in one operation:

$$CH_2ClCOOK + KCN = CH_2(CN).COOK + KCl$$
$$CH_2(CN).COOK + 2C_2H_5OH + 2H_2SO_4 = CH_2(COOC_2H_5)_2 + KHSO_4 + (NH_4)HSO_4.$$

Chloracetic acid (40 gms.) mixed with water (80 c.c.) is heated to 50–60° while potass. carb. (32 gms.) is added until the liquid is neutral and effervescence ceases. Powdered potassium cyanide (32 gms.) is now added and the whole well stirred. After the first reaction is over the mass is carefully heated till the temperature reaches 135° and then allowed to cool. The solid is then broken up, and the cyanacetate present is simultaneously hydrolysed and esterified by first mixing with 16 c.c. of alcohol, and then adding a mixture of alcohol (65 c.c.) and conc. sulphuric acid (65 c.c.) gradually, during ten minutes. The flask is then heated on the water-bath for one hour under a reflux condenser, after which the cool mixture is treated with 80 c.c. of water, filtered from insoluble matter, and the filtrate extracted several times with ether. The ethereal extract is washed with sodium carbonate solution and then dried over calcium chloride. After distilling off the ether, the remaining ester is distilled under reduced pressure. B.p. at ordinary pressure is 195°. B.p. at 80 mm. is 127°, at 60 mm. 120°, at 30 mm. 108°. Colourless liquid. Yield, 35–40 gms.

DropBooks

Mono-ethyl Malonic Ester.

Malonic ethyl ester (20 gms.) is added gradually to a solution of sodium (3 gms.) in ethyl alcohol (40 c.c.). The solid sodium salt separates out, and when all the malonic ester has been added the solid mass is mixed with ethyl iodide (25 gms.), which is added gradually and which causes the mass to become liquid. The mixture is then heated on a water-bath for one and a half hours, by which time sodium iodide has separated out and no alkaline reaction is obtained.

The alcohol is next distilled off, water added, and the mixture extracted with ether. After drying the extract over calcium chloride, the ether is removed and that portion of the remaining oil collected which distils at 206°–208°. Yield, 10–15 gms.

Hydrolysis and Conversion to Butyric Acid.

The ethyl malonic ester (10 gms.) is hydrolysed by boiling for an hour on the water-bath with strong aqueous potash containing 15 gms. of potash. The product is treated with moderately strong hydrochloric acid *till neutral*, and the acid is then precipitated as the calcium salt by adding a concentrated solution of calcium chloride. The salt is filtered and decomposed by strong hydrochloric acid and the free ethyl malonic acid extracted with ether. The ether extract deposits crystals on evaporation, and these may be recrystallised from a small quantity of boiling water. Colourless prisms, m.p. 111·5°. Yield, about 5 gms.

If some of the acid be heated over a small flame, carbon dioxide is liberated and butyric acid remains.

$$C_2H_5.CH\begin{matrix}COOH\\COOH\end{matrix} = C_3H_7.COOH + CO_2$$

Diaceto-succinic Ester.

[Ann., 1880, **201**, 142.]

Solid sodium acetoacetic ester is first prepared by dissolving 5 gms. of sodium in 40 gms. of alcohol, and after adding an equal volume of dry ether, acetoacetic ester (28 gms.) diluted with its own volume of ether, is gradually added with shaking.

To the mixture 1 c.c. of water is then added and the whole well stirred; this causes the sodium compound to separate, and it is filtered and drained on the pump. Yield, 20–25 gms.

The sodium compound is mixed into a thin paste with ether, and an ethereal solution of iodine then added till no more sodium iodide precipitates. The mixture is allowed to stand some hours and then filtered. The ethereal solution is shaken with mercury to remove iodine, after which it is crystallised from dilute alcohol or 50 per cent. acetic acid. White crystals, m.p. 78°. Yield, 10 gms.

Ethane Tetra-carboxylic Ester.

[Ber., 1884, **17**, 2781.]

Sodium (2·3 gms.) is dissolved in alcohol (30 gms.), and to the cold solution is added malonic ethyl ester (16 gms.). To the clear mixture, ether is added till a turbidity appears, and then iodine (12·7 gms.),

dissolved in ether, is added gradually with shaking. After standing a short time, water is added to dissolve sodium iodide, and the separated ethereal layer shaken with thiosulphate solution to decolorise it. After separating and drying over calcium chloride, the ether is removed and the remaining oil solidifies on cooling. Colourless prisms, m.p. 76°. Yield, about 8 gms.

Acetyl Acetoacetic Ester.

[Ber., 1884, **17**, Ref. 604.]

Dry sodium acetoacetic ester (20 gms.), which is prepared according to the method given under di-aceto-succinic ester, is dissolved in ether, and acetyl-chloride (12 gms.) is added slowly. A vigorous reaction takes place, which may be completed by warming, after which a little water is added to dissolve sodium chloride, and the ethereal layer separated. After removal of the ether the remaining oil is distilled under reduced pressure. B.p. at 50 mm. is 122–124°. Yield, about 20 gms.

Antipyrine.

[Ann., 1887, **238**, 147, 160.]
[Ber., 1883, **16**, 2597.]
[D.R.P. 26429.]

Phenyl hydrazine (10 gms.) is added to aceto-acetic ethyl ester (12·5 gms.) and well shaken; much heat is evolved, and when the reaction is over the oily product is separated from the water formed, and heated on the water-bath till a sample poured into water becomes solid (2 hours). The whole is poured while still warm into ether, the white precipitate

collected, well washed with ether, and then dried recrystallised from alcohol.

The phenyl-methyl-pyrazolon is then methyl by heating with the calculated amount of me iodide in methyl alcohol at 100°–150°, in a sealed t for one or two hours. The hydriodide of antipy present in the contents, is decomposed by aqu potash, and the antipyrine obtained is then crys lised from toluene or ether. M.p. 114°. Yi about 10 gms.

Mono-methyl Succinic Ester.

[Trans., 1899, **75**, 839.]

β-Methyl-cyano-succinic ester is first prepared mixing cyan-acetic ester (28·5 gms.) with 5·7 gms sodium dissolved in 70 gms. of alcohol, and t adding *very carefully* to the thick paste, 42 gms α-brom-propionic ester. The sodium compo dissolves with evolution of heat, and sodium brom separates. After an hour on the water-bath, neutral liquid is cooled and poured into water, the oil which separates is extracted with ether. ether extract is washed with dilute sodium carbon solution and then with water, and after drying o calcium chloride the ether is distilled off; the maining yellow oil is fractionated under 24 m pressure. The greater portion distilling betw 140°–165° is collected and refractionated under 17 m pressure, and that part collected which passes ove 160°–165°. Yield, 60 per cent.

The cyano-succinic ester thus obtained, is hyd lysed by boiling with six times its volume of co

DropBooks

hydrochloric acid under a reflux condenser for five hours. Any acid which separates on cooling is filtered, the liquid is made alkaline with ammonia, and boiled with 25 per cent. calcium chloride to precipitate the calcium salt of the acid, which is filtered and treated with hydrochloric acid to separate the methyl succinic acid.

Succino-succinic Ester. *p*-Diketo-hexamethylene.

[Ann., 1882, **211**, 308.]
[Ann., 1885, **229**, 45.]
[Ber., 1889, **22**, 2168.]

Sodium (10 gms.), cut into small pieces, is added to succinic ester (38 gms.) containing two or three drops of alcohol. The mixture soon becomes semi-solid, and is allowed to stand for ten days with occasional shaking.

At the end of this time the mass is broken up, acidified with dilute hydrochloric acid, and the insoluble ester is then filtered and recrystallised from alcohol. Colourless crystals, m.p. 126°. Yield, about 20 gms. N.B.—A smaller quantity can be obtained in less time if a little ether be added to the mass, and the mixture be heated on the water-bath for about twenty hours, during three days.

To obtain *p*-dikoto-hexamethylene, the ester is hydrolysed with sodium hydroxide, and the acid (succino-succinic) precipitated by acidifying. This acid is then heated to 200°, when it loses carbon dioxide and the diketo-body remains; m.p. 78°.

Another method is to hydrolyse the ester with con-

centrated sulphuric acid, when it loses carbon dioxide and passes directly to *p*-diketo-hexamethylene.

Tin Tetraphenyl.

[Ber., 1889, 22, 2917.]

Twenty-five gms. of tin-sodium alloy (25 per cent. sodium) is prepared by adding sodium in small pieces to strongly heated molten tin, in an iron crucible. The alloy when cold is broken up into small pieces and mixed with 30 gms. of brombenzene in a flask, and 1 to 2 gms. of acetic ester added. The mixture is then boiled under a reflux condenser in an oil-bath for ten hours. The brown semi-solid mass is next extracted with benzene and the extract crystallised. Colourless prisms; m.p. 226°. Yield, 10–15 gms.

DropBooks

Lead Tetraphenyl.

[Ber., 1887, 20, 716.]

This is prepared in the same manner as tin tetraphenyl, using 25 gms. of powdered lead-sodium (8 per cent. sodium) and the same quantity of brombenzene. The mixture should be boiled for fifteen hours and then extracted with benzene. Pale yellow needles; m.p. 224°. Yield, about 18 gms.

Mercury Diphenyl.

[Ann., 1870, **154**, 93.]

Brombenzene (31·5 gms.) is dissolved in an equal volume of xylene, and heated with 400 gms. of sodium amalgam (2 per cent. sodium) at 160° in an oil-bath. A small amount of acetic ester (about 1 gm.)

accelerates the reaction and boiling is continued during four hours. The clear liquid is then filtered hot, and the crystalline substance which separates from the xylene on cooling is recrystallised from benzene.

Colourless needles; m.p. 120°. Yield about 15 gms.

Silicon Tetraphenyl.

[Ber., 1885, **18**, 1541.]
[Ber., 1886, **19**, 1012.]

$$SiCl_4 + 4C_6H_5Cl + 8Na = Si(C_6H_5)_4 + 8NaCl$$

Silicon tetrachloride (20 gms.) is mixed with chlorbenzene (56 gms.) and four times the volume of dry ether, and a small quantity of acetic ester (1 to 2 gms.) added. The flask is attached to a reflux condensor, and then sodium (23 gms.) in small pieces is gradually added. A vigorous reaction follows and the flask should be repeatedly shaken. When the reaction is completed, water is added to remove any unattacked sodium, and then enough to dissolve the sodium chloride, after which the mixture is extracted with hot benzene. White crystals separate from the benzene solution, m.p. 228°.

Oxalyl-acetic Ester.

[Ber., 1886, **19**, 3325.]

Oxalic ester (20 gms.) is mixed with ether (100 gms.) and sodium (3 gms.) in thin slices. Acetic ester (12 gms.) is then added from a dropping-funnel, slowly, and after twelve hours the mass which has solidified is treated in the same way as

for the separation of acetoacetic ester (see p. 111). Yield, 50 to 60 per cent. A colourless oil, which crystallises with difficulty.

Method 2.

[Ann., 1893, 277, 375.]

Sodium ethoxide (9 gms.) is prepared by dissolving 3 grm. of sodium in a small quantity of ethyl alcohol and then distilling off the latter in a stream of dry hydrogen gas. The distillation should be conducted in an oil-bath and the temperature allowed to rise to 200° in order to drive off all alcohol. Oxalic ester (20 gms.) is then added and enough ether to give a clear solution; acetic ester (12 gms.) is next added, and the whole is boiled under a reflux condenser for one hour.

After this, the cool mixture is decomposed with cold dilute sulphuric acid, the ester is extracted with ether, and after drying over calcium chloride the ethereal solution is allowed to crystallise. Yield, about 50 per cent.

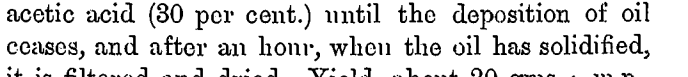
DropBooks

HYDROXYMETHYLENE-CAMPHOR.

[Ann., 1894, 281, 328.]

In a litre-flask, dry ether (20 c.c.) is mixed with sodium (8 gms.) in thin slices. The flask is attached to a reflux condenser fitted with a dropping-funnel, and camphor (50 gms.), dissolved in 200 c.c. of dry ether, is added to the ether and sodium, after which amyl formate (45 gms.) is added gradually from the dropping-funnel to the well cooled mixture in the flask.

The reaction is allowed to moderate after each addition of 4 or 5 gms. of the formate, and the flask is shaken occasionally. About half an hour is taken to add all the formate, and the mixture is then allowed to stand for two hours, by the end of which time most of the sodium will have dissolved and the mixture will be semi-fluid and brown. After standing another four hours to allow the sodium salt to separate, the whole is poured into 200 c.c. of iced water. The yellow aqueous layer is extracted twice with ether to remove any camphor or borneol in it, and finally air is blown through it to remove all ether. The aqueous solution is then treated with ice-cold acetic acid (30 per cent.) until the deposition of oil ceases, and after an hour, when the oil has solidified, it is filtered and dried. Yield, about 20 gms.; m.p., 70°–76°:



$$2C_{10}H_{16}O + 2Na + HCOOC_5H_{11} = C_5H_{11}\text{–}\underset{\displaystyle CO}{\overset{\displaystyle C:CHONa}{\overset{|}{C}}}\text{–}H + C_{10}H_{17}ONa + C_5H_{11}OH$$

Acetyl Acetophenone.

[Ber., 1905, **38**, 695.]
[D.R.P. 49542.]

Acetic ester (19 gms.) and acetophenone (24 gms.) are mixed with 150 gms. of *dry ether* and the mixture cooled in ice, while powdered sodamide (16 gms.) is gradually added. When the sodamide has all been added, the mixture is allowed to stand for a day, during which time a thick paste of sodium salt separates. At the end of this period ice-water is added; the aqueous layer is separated from the ether, and all

traces of ether blown out of it; it is then acidified with acetic acid, and the precipitated ketone filtered off. Crystals; m.p., 60°–61°; yield, about 25 gms.

Preparation of Sodamide.

[Trans., 1894, **65**, 504.]

Ammonia gas is passed over sodium heated in a glass tube to a temperature of 300°–400°. Since the glass is attacked, the sodium should rest in a trough of nickel foil. When powdering the sodamide, it should first be moistened with benzene, since it is very hygroscopic.

Ethyl Acetophenone.

[Ber., 1905, **38**, 698.]

DropBooks

Acetophenone and ethyl iodide in molecular quantities are mixed, and sufficient *dry ether* added to dissolve them (several volumes). One molecular quantity of sodamide is then added gradually with cooling, and after a while ammonia gas is evolved and the ether boils. After standing twenty-four hours, ice-water is added and the ethereal layer separated. This contains acetophenone, together with mono- and di-ethyl derivatives, which are separated by fractional distillation. B.p. of ethyl acetophenone, 227°–233°.

Furfurol Acrolein.

[Ber., 1880, **13**, 2342.]

Furfurol (1 part) is mixed with acetaldehyde (2 parts), water (100 parts), and 10 per cent. sodium hydroxide (5 parts).

By gradually heating the mixture to 50°–60° a yellow oil first separates, passing to a brown solid, and when the latter appears, the liquid is neutralised with sulphuric acid. The liquid is next distilled, and the distillate (containing needle-crystals) is extracted with ether, the ethereal extract distilled, and when the temperature has reached 210° the residual oil is allowed to solidify. The brown needles of furfurol acrolein are recrystallised from boiling water. Pale yellow needles; m.p. 51°; yield, about 60 per cent. of furfurol used.

Cinnamyl-vinyl-methyl Ketone.

[Ber., 1885, **18**, 2320.]

Acetone (30 gms.) is shaken with water (3600 gms.) till dissolved, and then cinnamic aldehyde (40 gms.) is added and shaking continued till a white emulsion is obtained. Sodium hydroxide (40 gms. of 10 per cent. aqueous solution) is then added, and the whole is allowed to stand forty-eight hours, with occasional agitation. At the end of this time the ketone will have completely crystallised. It may be recrystallised from ether. Rhombic plates; m.p. 68°.

Acetic Anhydride.

[Ber., 1911, **44**, 3333.]

Acetyl chloride (40 gms.) is mixed with potassium nitrate (7 gms.) in a flask attached to an upright condenser, which is closed by a calcium chloride tube. A vigorous reaction is accompanied by the evolution of chlorine and nitrosyl chloride, and after standing

for half an hour, the mixture is heated on a water-bath and gradually raised to boiling temperature, at which it is maintained for two hours. The colourless liquid mass is then extracted with ether to remove the potassium chloride, and the ethereal extract fractionally distilled. Yield, 15 to 20 gms.; b.p., 138°.

Benzoin from Benzaldehyde.

[Ann., 1840, **34**, 186.]

Benzaldehyde (25 gms.) mixed with potassium cyanide (5 gms. in 20 c.c. of water) and absolute alcohol (50 c.c.), is heated on a water-bath under a reflux condenser for half an hour. At the end of this time the benzoin crystallises out and may be filtered, washed with a little alcohol and recrystallised from spirit. Colourless prisms, m.p. 137°. Yield about 20 gms.

DropBooks

Desyl-acetophenone.

[Trans., 1890, **57**, 644.]

Acetophenone (18 gms.) is mixed with benzoin (31 gms.), potassium cyanide (4 gms.), water (75 gms.) and alcohol (75 gms.). The mixture is boiled on the water-bath and if necessary a little more alcohol may be added to dissolve the benzoin. After half an hour, desyl-acetophenone separates as an oil, and after 1¼ hours, the boiling is stopped, and the oil allowed to settle and separate. On cooling, the oil solidifies, and after draining on a plate is recrystallised from alcohol. Pale-yellow crystals; m.p. 126°. Yield, about 18 gms.

PHENANTHROXYLENE ACETOACETIC ESTER.

[Ber., 1883, **16**, 276.]

Finely powdered phenanthraquinone (33 gms.) is mixed in a flask with acetoacetic ester (30 gms.) and 150 c.c. of potassium hydroxide solution (one part KOH to six parts water) added. The mixture is gently warmed with continual shaking, heat is evolved, and the red colour of phenanthraquinone gives place to the light grey of the crude product.

This is boiled with water, washed with alcohol and recrystallised from benzene. Yield, about 30 gms.

White silky needles, which blacken and decompose at 185°.

APPENDIX II

PRACTICAL WORK: COPPER AND SILVER

Acrolein → β-Iodopropionic Acid.

Acrolein is prepared from glycerol by mixing the latter substance with twice its weight of powdered acid potassium sulphate, and after standing two days, distilling the mixture in a retort; two layers collect in the receiver, the upper of which is acrolein. This aqueous distillate is shaken up with powdered litharge until no more lead sulphite is produced, and it is then distilled on a water-bath. The moist acrolein which collects, is allowed to stand over calcium chloride for two hours and then redistilled. B.p. 52°. Yield, about 35 per cent.

The acrolein is next oxidised to acrylic acid as follows: An alkaline silver oxide solution is prepared by dissolving silver nitrate (1 part) in water (10 parts), and mixing with sodium hydroxide (1 part), also dissolved in water (10 parts).*

Ammonia solution is then added gradually till the precipitated silver hydroxide *just dissolves*. A quantity of this solution, sufficient to oxidise the acrolein taken, is warmed to 60°–70° *on the water-bath*, and

* These quantities should not be departed from and the solution should not be allowed to evaporate, otherwise silver fulminate may be formed and a dangerous explosion may result.

DropBooks

the acrolein, dissolved in the minimum amount of water, is added gradually; when all has been added the heating is continued for half an hour, with occasional shaking.

After this the mixture is acidified with hydrochloric acid and the acrylic acid separated by distillation with steam.

The acid distillate is neutralised with lead carbonate, heated and filtered, after which, the dry lead salt is decomposed by heating it in an inclined tube, through which passes a current of dry hydrogen sulphide. B.p. 140°.

$$2CH_2:CH.CHO + 3Ag_2O = 2CH_2:CH.COOAg + 4Ag + H_2O$$

The acrylic acid is now dissolved in the minimum quantity of water, and the calculated amount of concentrated hydrogen iodide solution gradually added, shaking well after each addition. When all has been added, the mixture is warmed on the water-bath for one hour and then evaporated to crystallisation; the resulting β-iodopropionic acid melts at 82°.

Adipic Acid.

[Ann., 1869, **149**, 220.]

β-Iodopropionic acid is melted in a small flask with finely divided silver in slight excess of that calculated from the equation:

$$2CH_2I.CH_2.COOH + 2Ag = 2AgI + (CH_2)_4(COOH)_2.$$

The silver is prepared by suspending silver iodide or silver chloride in water, and adding the necessary amount of zinc dust. The precipitated silver is filtered, washed with dilute hydrochloric acid to

remove any zinc, and then dried by heating gradually to 150°.

The molten mixture of iodo-acid and silver is maintained at 100°–120° until it thickens and the temperature is then raised to 150°–160°. After remaining at this temperature for two or three hours the mixture is cooled and then extracted with boiling water. The aqueous extract, on evaporation, deposits a considerable crust of adipic acid which is separated. A further quantity of adipic acid is obtained by evaporating the mother-liquor, and the whole may be recrystallised from hot water. Colourless crystals; m.p. 148°–149°.

Adipic acid is more conveniently prepared by the following method, from γ-chlorobutyronitrile ($Cl.CH_2.CH_2.CH_2.CN$), which is itself prepared from trimethylene chlorobromide as follows:

To a hot solution of potassium cyanide (80 gms.) dissolved in 125 gms. of water, hot 96 per cent. alcohol is added (500 c.c.), and to this clear, hot mixture, trimethylene chlorobromide (200 gms.) is added; the whole is then boiled for 1½ hours on the water-bath under a reflux condenser. The alcohol is next distilled off, and carries with it most of the unchanged trimethylene chlorobromide. Water is then added to the residue in the flask to dissolve potassium salts, and the oily layer is distilled after drying over calcium chloride. After two or three fractionations the portion boiling at 192°–205° is taken as γ-chlorobutyronitrile. B.p. 195°–197°. Yield, 50 per cent.

[Ber., 1890, **23**, 1771.]
[Trans., 1901, **79**, 130.]

The nitrile, prepared as above, is next digested with the calculated amount of sodium malonic ethyl ester, on the water-bath, till no alkaline reaction is obtained. After removal of the alcohol and sodium chloride, the cyano-propyl-malonic ethyl ester is fractionally distilled under reduced pressure. B.p. 170°–175° at 40 mm.

This substance, $CN.CH_2.CH_2.CH_2.CH(COOC_2H_5)_2$, is then boiled with dilute sulphuric acid (1 : 2) for five hours; the resulting adipic acid is extracted with ether and purified by recrystallising from water.

Carbazole from Thio-diphenylamine.

[Ber., 1886, **19**, 2243.]

Thio-diphenylamine is prepared by heating a mixture of diphenylamine (30 gms.) and sulphur (12 gms.), at a temperature of 250°–280° for one hour or until hydrogen sulphide is no longer evolved. The mixture is then distilled (in a retort); any unchanged diphenylamine boils at 310°, while thio-diphenylamine distils at 370°. The distillate may be crystallised from alcohol. Yellow plates; m.p. 180°. Yield, over 50 per cent.

To prepare carbazole, the thio-diphenylamine is mixed in a retort with excess of copper powder and distilled in a stream of carbon dioxide. If the distillate has a yellow colour (due to thio-diphenylamine) it should be again mixed with copper powder and distilled. Colourless crystals, m.p. 238°; b.p. 355°. Yield, 60–70 per cent.

Di-orthonitrophenyl-diacetylene.

[Ber., 1882, **15**, 50.]

It is necessary to prepare first, *o*-nitro-phenyl-propiolic acid, which is itself obtained from *o*-nitro-cinnamic acid. Cinnamic ester (50 gms.) is nitrated by pouring gradually into cooled nitric acid (sp. g. 1·5).

After completing the nitration by warming on the water-bath for twenty minutes, the mixture is poured into water, and the mixed *o*- and *p*-nitro-esters separated by digestion with a little alcohol, in which only the ortho-compound dissolves. The substance may then be obtained in a pure state by pouring the alcoholic solution into cold water and filtering.

DropBooks

Bromination of o-Nitro-cinnamic Ester.

[Ann., 1882, **212**, 125.]

The ester (20 gms.) dissolved in carbon bisulphide (300 gms.) under a reflux condenser, is treated gradually with bromine (15 gms.) and warmed. The bromine soon disappears, and if the CS_2 be quite dry, no hydrogen bromide will be evolved. After warming a short time, part of the CS_2 is distilled off and the remainder evaporated. Pale yellow crystals will separate; m.p. 71°. Yield, 30 gms.

The ester is next treated with alcoholic potash as follows:

Di-brom-*o*-nitrocinnamic ester (12 gms.) is dissolved in alcohol, and potash (6 gms.), also dissolved in alcohol, is added slowly. Potassium bromide at

once separates, and when all the potash has been added the liquid is filtered from bromide, part of the alcohol distilled off, and the remainder evaporated over sulphuric acid. The dark brown liquid deposits crystals (mixed with resin), which are poured into water and extracted with ether to remove impurities, after which the nitro-phenyl-propiolic acid is precipitated by sulphuric acid fractionally. A brown precipitate is first thrown down and removed, further addition of sulphuric acid throws down nitro-phenyl-propiolic acid, and more is obtained by extraction with ether. The slightly red crystals melt at 157°, and when subjected to a steam distillation give nitro-phenyl-acetylene.

The last-named compound is converted into the copper derivative by dissolving it in much alcohol and adding an ammoniacal solution of cuprous chloride. The resulting precipitate is washed with ammonia, then beaten to a pulp and air bubbled through it to remove ammonia; it may be recrystallised from chloroform.

In the final stage of the process this copper compound (1 part) is added to a solution of potassium ferricyanide (2¼ parts) and potassium hydroxide (0·4 part) in water (9 parts); this mixture is allowed to stand till the red colour of the copper compound disappears (24 hours). The green-brown residue is separated and after drying, extracted with chloroform; the di-phenyl-diacetylene nitro-compound crystallises in yellow needles.

o-Chlor-toluene.

[Zeit. angew. Chem., 1910, **23**, 389.]

o-Toluidine (53 gms.) is dissolved in a mixture of 170 gms. of 23 per cent. hydrochloric acid and 500 gms. of ice-cold water. It is diazotised by adding gradually, sodium nitrite (37 gms.) dissolved in water (80 gms.). The ice-cold diazo-solution is then added to a solution of cuprous chloride (50 gms.) in 23 per cent. hydrochloric acid (380 gms.) diluted with water (330 gms.). The temperature of the copper solution should be kept at + 5° during the mixing, and the process should occupy fifteen minutes. After standing a short time, the mixture is heated on the water-bath to drive off nitrogen and is then steam-distilled. The distillate is extracted with chloroform, the extract dried over calcium chloride, and after removal of chloroform the oil is distilled. B.p. 157°. Yield, about 50 gms.

DropBooks

o-Chlor-benzoic Acid.

o-Chlor-toluene is boiled in a flask under a reflux condenser, with a solution of potassium permanganate containing a weight of the oxidant equal to that of the chlor-toluene used. The time required is about ten to twelve hours and the permanganate solution may be added gradually. When the liquid has cooled two methods of treatment are possible: Either it may be filtered from precipitated manganese oxide and then acidified with hydrochloric acid to precipitate chlor-benzoic acid, or sulphur dioxide may be passed in straight away without filtering. The latter

process will dissolve the oxide of manganese and at the same time precipitate the chlor-benzoic acid. Colourless crystals; m.p. 137°. Yield, nearly quantitative.

p-Chlor-toluene (Gattermann).

[Ber., 1890, **23**, 1218.]

p-Toluidine (36 gms.), dissolved in a mixture of 40 per cent. hydrochloric acid (225 gms.) and water (150 gms.), is diazotised by 25 gms. of sodium nitrite dissolved in 100 c.c. of water. Copper powder (40 gms.) is then made into a paste with water and added gradually to the above diazo-solution during half an hour. After standing a short time the mixture is steam-distilled and the *p*-chlor-toluene separated by extraction with chloroform. B.p. 160°. Yield, about 35 gms.

Formaldehyde.

[J. Russ. Phys. Chem. Soc., 1913, **45**, 286.]

Methyl alcohol (100 c.c.) is placed in a flask which is kept at a temperature of 40°, and connected to a horizontal combustion tube in which a roll of copper foil (5 cm. long) is placed. The other end of the combustion tube is connected to a condenser and a well cooled receiver.

A stream of air is driven through the alcohol causing a mixture of air and alcohol vapour to pass through the copper coil, which should be heated until it just glows. The reaction will proceed without further heating and a solution of formaldehyde in methyl alcohol will collect in the receiver.

Small explosions on the copper do no harm, but the temperature should not exceed a dull red heat or some of the aldehyde will be decomposed.

A much improved yield (about 80 per cent.) may be obtained by substituting pumice, coated with a mixture of silver and copper, for the roll of copper foil.

For a method of estimating the percentage of formaldehyde obtained, see 'Volumetric Analysis,' by Sutton.

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APPENDIX III

PRACTICAL WORK: MAGNESIUM. CALCIUM

Benzoic Acid.

A solution of magnesium phenyl bromide in ether is prepared by mixing brombenzene (16 gms.) with *dry ether* (50 c.c.) and gradually adding magnesium ribbon (2·4 gms.). The reaction, which is fairly vigorous, may require to be started by the addition of a crystal of iodine. When all the magnesium has dissolved, the solution is cooled in iced water and a stream of well dried carbon dioxide passed through it for about three hours, at the end of which time the flask contains a solid mass of the addition product $C_6H_5.COO.MgBr$.

The solid mass is treated with 50 c.c. of ice-water with shaking, and then 40 gms. of cold 20 per cent. hydrochloric acid is added gradually. This process liberates benzoic acid, which may then be extracted with ether and crystallised.

Yield, about 10 gms.

Phenyl-ethyl-carbinol.

[Compt. rend., 1900, **130**, 1322.]

Magnesium ethyl iodide is prepared by mixing ethyl iodide (40 gms.) with *dry ether* (100 c.c.) and then adding magnesium ribbon (6 gms.). When all the magnesium has dissolved, the solution is cooled in ice, and benzaldehyde (25 gms.) in 50 c.c. of dry ether added gradually. The solid magnesium compound which separates is allowed to stand over-night and then ice-cold water (200 c.c.) is added, followed by sufficient hydrochloric acid (1 : 1) to just dissolve the magnesia. The ethereal layer is removed and washed, first with sodium carbonate solution, and then with sodium bisulphite to remove iodine, after which it is dried over potassium carbonate. The ether is distilled off and the phenyl-ethyl-carbinol distilled under reduced pressure. Yield, about 20 gms.

DropBooks

Trimethyl Carbinol.

Magnesium methyl iodide is prepared from methyl iodide (25 gms.), and magnesium (4 gms.) in dry ether (15 c.c.).

To this solution is added, gradually, acetone (10 gms.) in an equal quantity of ether, and the mixture is allowed to stand over-night. After this, dilute acid is added and the two layers which result are separated.

The ether is distilled from the ethereal layer and the trimethyl carbinol which remains is added to the acid aqueous solution; this is distilled with steam

until the addition of solid potassium carbonate ceases to "salt out" the carbinol. From the aqueous distillate the carbinol is salted out with potassium carbonate, separated, and dried over lime or barium oxide.

Yield, about 60 per cent.; b.p. 83°.

Triphenyl Carbinol.

Magnesium phenyl bromide is prepared by dissolving brom-benzene (16 gms.) in ether (80 c.c.) and adding gradually magnesium ribbon (2·4 gms.). The solution when ready, is treated with benzophenone (18 gms.) in ether (50 c.c.), and when the main reaction is over it is completed by boiling on the water-bath for half an hour.

A few lumps of ice are then added to the well cooled liquid, followed by dilute sulphuric acid. The ethereal layer is separated, washed with sodium carbonate solution and then dried over potassium carbonate, after which the ether is distilled off and the solid recrystallised from benzene. Yield, about 20 gms.; m.p. 159°.

Camphor from Camphoric Acid.

[Compt. rend., 1896, **122**, 293, 448.]

Camphoric Anhydride → Campholide → Homocamphoric Acid.

Camphoric anhydride is prepared by mixing camphoric acid (100 gms.) with acetic anhydride

(70 gms.) and acetyl chloride (11 gms.) and boil the mixture under a reflux condensor for half hour. After cooling, the anhydride is washed w water and recrystallised from alcohol. Yield, 8 90 per cent.; m.p. 221°.

The camphoric anhydride is dissolved in alco and an excess of 5 per cent. sodium amalgam ad gradually during 3 days, keeping the mixture l and continually acid by addition of conc. sulphu acid. The resulting campholide may be recryst lised from benzene. M.p. 216°.

The campholide is next heated in a sealed tu with the calculated amount of potassium cyanide 230° for six hours. When cold, the mass is tra ferred from the tube to water, in which unchang campholide is insoluble, and the aqueous solution extracted with ether to remove traces of campholi after which it is acidified with sulphuric acid precipitate homocamphoric nitrile. This substa is collected, recrystallised from alcohol or other a hydrolysed by boiling with 30 per cent. potash ammonia is no longer evolved. The mixture is th acidified and the precipitate of homocamphoric a filtered. M.p. 234°.

Homocamphoric acid is now neutralised with so solution and precipitated with lead acetate; the le salt of the acid is collected, dried, and then pack into a long combustion tube and heated gent Camphor sublimes and may be collected.

Camphoric acid is prepared from camphor heating 50 gms. with a mixture of 400 gms. nit acid (1·4) and 260 c.c. of water for twenty hours

a boiling water-bath. The mixture should be in a litre-flask, with a boiling tube, which contains cold water, fitted in the neck.

At the end of this time the mixture is well cooled, and the camphoric acid which separates is filtered off—about 30 gms.

The mother-liquor, about 600 c.c., is mixed with a further 80 c.c. of conc. nitric acid and camphor (50 gms.) added, and after heating for a further twenty hours, camphoric acid is separated as before (about 40 gms.). The mother-liquor is again treated with 130 c.c. of conc. acid and 60 gms. of camphor, and after a further twenty hours' heating, about 40 gms. more of camphoric acid is separated. In this way from 160 gms. of camphor, about 110 gms. of camphoric acid will be obtained—70 per cent. yield [Amer. Chem. Journ., 1894, **16**, 500].

PENTAMETHYLENE.

[Ann., 1893, **275**, 312.]

Adipo-ketone is produced by distilling the calcium salt of adipic acid in an iron or glass tube. The distillate is re-distilled, and that portion collected which boils at 128°–132°.

The ketone is then reduced by mixing it with an equal volume of ether in a flask fitted with a reflux condenser; an equal volume of water is then added and sodium in small pieces dropped in. When the required amount of sodium has been introduced, the ethereal layer is removed, dried over potassium hydroxide and the ether distilled off. The remaining

oil is fractionated and the portion collected which boils at 135°–145°; this is refractionated. The resulting cyclo-pentanol boils at 139°.

The alcohol is next cooled to 0° and saturated with hydrogen iodide; after standing over-night the liquid is shaken with dilute sodium hydroxide. A colourless oil separates, which can be distilled with little decomposition in a current of carbon dioxide at 164°–165°.

The iodide is now reduced to pentamethylene by mixing it with five times its weight of alcohol and some granulated zinc in a flask fitted with reflux condenser.

Fuming hydrochloric acid is added drop by drop, and after some time the solution becomes turbid and an oil separates, which, after standing during some hours with the zinc and acid, is separated, and any iodide present removed by shaking with a mixture of concentrated sulphuric and nitric acids. The liquid after separation is dried and distilled. B.p. 50°.

DropBooks

Cyanamide; Guanidine.

[J. angew. Chem., 1910, **23**, 2405.]

Sodium cyanamide (50 gms.) is gradually added to concentrated hydrochloric acid (1·19), 74 gms. while well cooled, and the water is then removed by distillation *in vacuo*. The residue, which solidifies on cooling, is extracted with ether, and the ether evaporated; the cyanamide solidifies when cooled. Yield, about 10 gms. M.p. 40°.

From calcium cyanamide the procedure is as follows: The calcium compound is dissolved in water and the calculated amount of aluminium sulphate added in solution; this liberates cyanamide, and a precipitate of calcium sulphate and alumina is formed. The filtrate is evaporated *in vacuo* and the cyanamide crystallised from ether. By this method about 20 gms. of cyanamide is obtained from 200 gms. of the calcium compound.

A good yield of guanidine nitrate is obtained by treating dicyanamide (obtained by heating cyanamide) with a mixture containing 25 per cent. of hydrochloric acid (1·19) and 35 per cent. of nitric acid (1·38), in water.

APPENDIX IV

PRACTICAL WORK: ZINC. MERCURY

Citric Acid.

[Trans., 1897, **71**, 457.]

Oxalyl-acetic ester (20 gms.) is mixed with monobromacetic ester (17 gms.) in a flask of 300 c.c. capacity, fitted with an air-condenser. Enough zinc turnings to cover the end of a spatula are added and the mixture becomes brown, while the temperature quickly reaches 50° and the zinc dissolves. Addition of a second portion of zinc is attended by boiling and the reaction is moderated by cooling; the metal is added in excess, and the mixture is then heated on the water-bath for a short time. After cooling, the mixture is treated with cold dilute sulphuric acid and ether, well shaken to get a clear solution, and the ethereal layer removed, washed with dilute sodium carbonate and dried over calcium chloride. The ether is next distilled and the remaining oil fractionated under reduced pressure; most of it passes over below 200° at 35 mm. That portion taken as citric ester (b.p. 212°–216°) is hydrolysed

DropBooks

by alcoholic potash. From the neutral solution calcium citrate is precipitated. Yield, about 5 gms.

KETONES OR TERTIARY ALCOHOLS FROM ACID CHLORIDES.

[Bull. Soc. Chim., 1911 (iv), 9, i-xxv.]

The zinc alkyl reagent is prepared as follows:

Twice the amount of zinc-copper couple theoretically required, is mixed with the alkyl iodide (1 mol.), ethyl acetate (⅓ mol.), and dry toluene equal to twice the weight of ethyl acetate used. This mixture is heated under a reflux condenser at 100°, and the reaction started, if necessary, by adding a crystal of iodine.

About forty-five minutes' heating is required, and towards the end, the temperature may be raised to 110°; the flask should be occasionally shaken. When refluxing has stopped, the contents of the flask are cooled, an amount of toluene equal to that first used is added, and the viscous liquid is decanted into a dry flask or bottle. Yield, about 80 per cent.

For use with acid chlorides the procedure is as follows:

An amount of the above reagent (zinc-alkyl-iodide) is taken (25 per cent. in excess of the calculated amount), and while cooled to 0°, the acid chloride dissolved in dry toluene is added drop by drop with shaking. When all the acid chloride has been run in, the mixture is cooled and dilute sulphuric acid added. The toluene layer contains the required product, and often a small quantity of zinc which may be removed by shaking with ammonia. After this the

toluene solution is washed with $NaHCO_3$ and also with thiosulphate; it is then dried over sodium sulphate before separating the ketone or tertiary alcohol.

Naphthalene from β-Naphthol.

A combustion tube is half filled with a mixture of zinc dust and β-naphthol (10 gms.). The remainder of the tube is filled with granulated pumice impregnated with zinc dust, and this (the front end) is connected to a receiver. The other end of the tube is connected to a generator for providing a stream of dry hydrogen. The combustion tube should be between 50 and 60 cm. long, and rest in a furnace. When all air has been expelled by hydrogen, the zinc-pumice is heated to redness and then the naphthol mixture is heated.

PrepBooks

In the receiver, naphthalene and water collect, and when the distillation is complete, the aqueous distillate is extracted with ether and the ethereal solution dried over calcium chloride. On evaporating the ether, naphthalene remains.

Isoquinoline.

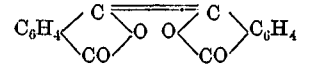
[Ber., 1888, **21**, 2299.]
[Ber., 1884, **17**, 2178.]

Phthalic Anhydride → Phthalide → Homophthalimide.

Phthalic anhydride (200 gms.) is dissolved in glacial acetic acid (1 kilo.), and while heated on the water-bath, zinc dust (300 gms.) is gradually added.

The zinc dissolves rapidly with evolution of heat and when the reaction becomes sluggish, heat is applied.

Needles of diphthalyl—



which deposit on cooling are filtered off, and on diluting the mother-liquor a mixture of hydrodiphthalyl and hydrodiphthal-lactonic acid is precipitated. After filtering these off, the phthalide is extracted from the mother-liquor with ether. Prisms; m.p. 73°. Yield, about 30 per cent.

The phthalide is next converted to cyanotoluic acid by heating it in a sealed tube with the calculated amount of potassium cyanide at 230°–240°, for five or six hours.

The contents of the tube are then transferred to water, filtered from any insoluble matter, and the nitrile precipitated by sulphuric acid. When filtered, it is hydrolysed by boiling with 30 per cent. potash till no more ammonia is evolved, after which homophthalic acid is precipitated by sulphuric acid. M.p. 175°.

Homophthalic Acid → Homophthalimide.

[Ber., 1886, **19**, 1653.]

The ammonium salt is prepared by neutralisation with ammonia, and then distilled, when it decomposes into homophthalimide, water and ammonia. The two latter substances pass over first, and leave behind homophthalimide, which melts at 223°.

The homophthalimide is then mixed with zinc dust

in a combustion tube and heated in a stream of hydrogen, at a dark red heat.

A deep-brown liquid distils over which smells of isoquinoline, and this is saturated with hydrogen chloride, the hydrochloride of the base filtered and dried, and it may then be decomposed by aqueous potash. The isoquinoline, which may be obtained by extraction of the alkaline liquor with ether, or distillation with steam, may be further purified by formation of the picrate and its subsequent decomposition. M.p. 23°. B.p. 241°.

Fluorescein.

[Ann., 1876, **183**, 3.]

Resorcinol (7 parts) is mixed with phthalic anhydride (5 parts), and powdered anhydrous zinc chloride (3 parts) is gradually added to the mixture, with stirring, at a temperature of 180°. When all the zinc chloride has been added, the mass is heated to 210° for two hours. The cooled mass is then pulverised and boiled with dilute hydrochloric acid for ten minutes, after which the solid fluorescein is filtered and washed. It may be purified by recrystallising from alcohol. Yield, about 80 per cent.

Malachite Green.

[Ann., 1881, **206**, 122.]

Dimethylaniline (5 parts) is mixed with benzaldehyde (2 parts) and powdered anhydrous zinc chloride (4 parts).

This mixture is heated on the water-bath, in a basin, until it no longer smells of benzaldehyde (four to five hours).

The product is then transferred to a large flask and distilled with steam to remove unchanged dimethyl-aniline; the leuco-base is filtered when cool and recrystallised from alcohol. Almost a quantitative yield is obtained. The zinc chloride double salt of the dye is prepared as follows: Ten gms. of the base is dissolved in dilute hydrochloric acid containing 2·7 gms. of HCl; the liquid is diluted with 800 c.c. of water and 10 gms. of 40 per cent. acetic acid added; it is then cooled with ice, and a thin paste of 7·5 gms. of lead peroxide added gradually with shaking. After standing a few minutes, the lead is precipitated by adding 20 per cent. sodium sulphate, and to the filtrate from lead sulphate is added 8 gms. of zinc chloride dissolved in a little water. The dye is then salted out by addition of common salt. Yield, about 7 gms.

Acridine.

[Ber., 1884, **17**, 101.]

Diphenylamine (1 part) is mixed with chloroform (1 part), zinc chloride (1 part), and zinc oxide (½ a part). The mixture is placed in a sealed tube and heated to 200°–210° for seven to eight hours. The mixture is then digested with conc. hydrochloric acid and the filtered solution poured into water to precipitate any unchanged diphenylamine, the hydrochloride of which is dissociated by water. From the

filtered solution, acridine is precipitated by sodium hydroxide, and may be recrystallised from hot water after separating by steam distillation. Fine leaflets. M.p. 110°. Yield, about 50 per cent.

α-Methyl-indole.

[Ber., 1886, **19**, 1563.]

Acetone phenyl-hydrazone is first prepared by mixing phenyl-hydrazine (30 gms.) with acetone (18 gms.). The mixture becomes warm and water separates; it is then heated on the water-bath for half an hour, and at the end of this time heated in a dish on the water-bath, to drive off acetone and steam. The hydrazone is then mixed with five times its weight of anhydrous zinc chloride, and heated under a reflux condenser in an oil-bath at 180°. A vigorous reaction takes place, and when completed, the dark-coloured mass is distilled with steam. The α-methyl-indole collects in the receiver and soon solidifies to a pale yellow mass. It may be purified by recrystallising from ligroin. M.p. 59°. Yield is over 60 per cent. of that calculated.

Propyl Chloride.

[J. Am. Chem. Soc., 1907, **29**, 1328.]

Anhydrous zinc chloride (30 gms.) is melted in a round flask (½-litre), which is rotated so that the cooled chloride forms a layer inside, with a large surface exposed. The flask is fitted with a three-holed cork through which pass two dropping funnels and a fractionating column; the last is fitted with a

thermometer and the side tube passes into a vertical spiral condenser. Through a second hole at the top of the condenser, a tube is passed for dropping cold water, so that hydrogen chloride may be absorbed. Propyl alcohol (54 gms.) is required and phosphorus trichloride (30 gms.). One half of the trichloride is run in from the funnel which reaches to the bottom of the flask, and while heating gently, one third of the alcohol is admitted drop by drop through the second funnel which reaches just above the level of the mixture. When this portion has been added the remaining phosphorus trichloride and alcohol are added simultaneously and at the same rate. Propyl chloride distils over, mixed with hydrogen chloride continuously, but the latter is prevented from escaping into the air, by dropping water at a suitable rate into the condenser. The distillation (hitherto conducted on a water-bath) is finished over a flame, and the propyl chloride separated and dried over calcium chloride. Yield, 80–90 per cent. B.p. 44°.

a-Ethoxy-quinoline.

[Ber., 1882, **15**, 2103.]

o-Amino-cinnamic ester (20 gms.), prepared by reducing *o*-nitro-cinnamic acid and then esterifying the resulting amino-acid (see p. 162), is warmed with a saturated alcoholic solution of zinc chloride for some hours at 80°–90°. The mixture is then made alkaline and distilled with steam, when the quinoline derivative passes over and may be extracted from

the distillate with ether. After drying the extract over potassium carbonate and removing the ether, the remaining oil is distilled. B.p. 256°.

Phthalic Acid.

[D.R.P. 91202.]

Naphthalene (20 gms.) is mixed with mercuric sulphate (10 gms.) and concentrated sulphuric acid (300 gms.) in a retort which is fixed upright, and warmed until the naphthalene has dissolved. The retort is then turned, connected with an air-condenser and heated strongly. Reaction commences at 200°–250° and becomes vigorous at 300°, while the products distilling over, consist of phthalic acid, sulphophthalic acid, naphthalene, and water, accompanied by sulphur dioxide and carbon dioxide. The distillate is collected in 250 c.c. of cold water and heating continued till the retort is nearly dry, after which the distillate is filtered. The precipitate is washed with water and then dissolved in sodium hydroxide, filtered from unchanged naphthalene, and the phthalic acid re-precipitated by hydrochloric acid. It may be recrystallised from water or alcohol. Yield, about 70 per cent.

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APPENDIX V

PRACTICAL WORK: ALUMINIUM. TIN. LEAD

DIMETHYL-ANILINE-PHOSPHOR-CHLORIDE

[Ber., 1888, **21**, 1497.]

Phosphorus trichloride (33 gms.) is mixed with dimethyl-aniline (23 gms.) in a flask fitted with a reflux condenser.

Anhydrous aluminium chloride (7 gms.) is then added, through the condenser, a little at a time whereby a vigorous reaction ensues. When all the chloride has been added, the flask is heated on a water-bath for three hours, and then when cool, the oily liquid is extracted two or three times with petroleum ether (until the residue in the flask is nearly solid).

On distilling the clear extract over a water-bath, the petroleum ether is removed, and the residue on cooling separates in tables. It may be purified by recrystallisation from ether or benzene.

Yellow crystals; m.p. 66°. Yield, about 50 per cent.

p-Toluic-aldehyde.

[Ber., 1897, **30**, 1622.]

Toluene (30 gms.) is mixed with anhydrous aluminium chloride (45 gms.) and cuprous chloride (4 gms.) in a flask, and into the mixture a stream of carbon monoxide and hydrogen chloride gases is passed, while the flask is continually shaken and the temperature maintained at 20°–25°. The carbon monoxide may be stored in a 10-litre bottle and is enough to pass steadily for about three hours. The hydrogen chloride should pass at half the rate of the carbon monoxide. The escaping gases may be collected in a second bottle and used over again.

At the end of three hours the reaction-product is poured into ice-water; an oily layer separates, and the mixture is distilled with steam to remove toluene and toluic aldehyde. The aqueous distillate is shaken with saturated sodium bisulphite, and undissolved toluene separated from the aqueous layer. If the aldehyde bisulphite separates at this stage it must be dissolved by adding more water.

Finally, the separated aqueous solution is made alkaline with sodium hydroxide and distilled with steam; the aqueous distillate is then extracted with ether, and after drying over calcium chloride the ether is removed by distillation. Yield, about 20 gms. of oil; b.p., 204°.

Diphenyl Methane.

[Trans., 1895, **67**, 826.]

Benzene (60 gms.) is placed in a flask under a reflux condenser and half a gram of aluminium-

mercury couple added in strips. The couple is prepared by immersing aluminium foil in concentrated mercuric chloride solution for a minute; the mercury-coated strips are first washed with water, then with alcohol, and lastly with benzene, and dropped quickly into the benzene in the flask. Benzyl chloride (30 gms.) is then added slowly, from a tap-funnel in the top of the condenser, during one hour. Effervescence is caused by the evolution of hydrogen chloride, and when all has been added the flask is heated for a short time on the water-bath (quarter of an hour).

The liquid is then shaken up with dilute sodium hydroxide solution, the benzene layer separated and fractionally distilled. When the temperature reaches 100°, the distillation is continued under diminished pressure (80 mm.) and the fraction collected which passes over at 170–176°. On cooling, this forms a mass of colourless needles (diphenyl methane). M.p. 25°. Yield, about 14 gms.

α-Hydrindone.

[Trans., 1894, **65**, 484.]

Hydrocinnamic Acid → β-Phenyl-propionyl Chloride.

Cinnamic acid (1 part) is mixed with water (10 parts) and neutralised with sodium hydroxide. To this solution, 2½ per cent. sodium amalgam (17 parts) is gradually added with shaking, after which the liquid is poured off from the mercury, and the

hydrocinnamic acid precipitated by hydrochloric acid. Yield, 80–90 per cent.; m.p. 47°.

The acid chloride is prepared by treating the acid (50 gms.) in a flask, gradually, with phosphorus pentachloride (69 gms.); the reaction may be completed by warming on the water-bath. To remove phosphorus oxychloride, the liquid is distilled under diminished pressure; subsequently the pressure is reduced to below 35 mm. before the β-phenyl-propionyl chloride can be distilled without decomposition. B.p. 125°–135° at 33 mm. and 117°–119° under 13 mm. Yield, about 90 per cent.

β-Phenyl-propionyl chloride (25 gms.) is dissolved in petroleum ether (b.p. 60°–70°), and after adding anhydrous aluminium chloride (25 gms.) the mixture is heated gently, under a reflux condenser, on the water-bath, till the mixture boils and a vigorous evolution of hydrogen chloride takes place; the flask is then removed till the reaction subsides.

This heating on the water-bath and subsequent cooling, is repeated until the evolution of hydrogen chloride is small (20–30 mins.). After treatment with ice-cold water the mixture is steam distilled, and the hydrindone in the receiver is extracted with petroleum ether, washed with sodium carbonate and crystallised.

Colourless crystals; m.p. 41°. Yield, about 10 gms.

Triphenyl-methane.

[Ber., 1893, **26**, 1961.]

Dry benzene (160 gms.) is mixed with dry chloroform (32 gms.) in a flask connected with a reflux

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condenser, and powdered aluminium chloride (25 gms.) is added gradually, with shaking.

Hydrogen chloride is evolved, and when all the aluminium chloride has been added, the flask is heated to boiling for half an hour.

When cold, the mixture is added to an equal volume of cold water, and the upper benzene layer which contains the triphenyl-methane, is separated and dried over calcium chloride. Benzene is then distilled off and the temperature finally raised to 200°, after which any diphenyl-methane is removed by distilling under 80 mm. pressure. B.p. 175°. When the thermometer rises above 180°, the distillation is stopped and the residue, when cool, extracted with warm benzene.

The crystals obtained from this liquid contain benzene of crystallisation which is removed by heating on the water-bath; the triphenyl-methane may be recrystallised from alcohol. Colourless plates; m.p. 92°. Yield, 20–25 gms.

Acetophenone.

Aluminium chloride (60 gms.) is powdered, and covered with benzene (36 gms.) in a half-litre flask fitted with a reflux condenser, and acetyl chloride (42 gms.) is gradually added to the well cooled mixture through a tap-funnel. A vigorous evolution of hydrogen chloride takes place and the mixture is allowed to stand for an hour, after which it is stirred and poured into 300 c.c. of ice-cold water. The aluminium compound decomposes with evolution of

heat, and the dark oil which separates is extracted with benzene. The benzene extract, after washing with dilute caustic soda and then with water, is dried over calcium chloride and distilled. Benzene passes over first and the thermometer then rises rapidly to 190°; that portion is collected as acetophenone which distils at 195°–200°. The pale yellow oil solidifies on cooling. Yield, about 25 gms. Colourless plates; m.p. 20°, b.p. 202°.

o-Benzoyl-benzoic Acid.

[Ber., 1880, **13**, 1612.]

Phthalic anhydride (25 gms.) is dissolved in warm benzene (250 gms.), and dry aluminium chloride (40 gms.) is gradually added during three quarters of an hour. After standing for a short time the cooled benzene layer is poured off and decomposed by dilute hydrochloric acid, when a yellow mass separates, which is washed with water and then treated with warm sodium carbonate solution, whereby most of the solid dissolves. The acid (benzoyl-benzoic) is reprecipitated by acidifying the solution of the sodium salt, and may be recrystallised from xylene. Yield, about 15 gms.

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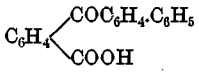
Phenyl-benzoyl-benzoic acid—



may be prepared similarly, using diphenyl and phthalic anhydride.

[J. Prakt. Chem., 1890, **149**, 147.]

Benzoyl-benzoic Acid → Anthraquinone.

The acid is dissolved in conc. sulphuric acid and heated to 100° for half an hour. On pouring into water, a white precipitate of crude anthraquinone is formed, which is washed with water and then with sodium hydroxide solution.

It is then recrystallised from glacial acetic acid and further purified by sublimation. Yellow needles; m.p. 275°.

Hydrolysis of Anisole by $AlCl_3$.

[Ber., 1892, 25, 3531.]

Anisole (10 gms.) is mixed gradually with powdered anhydrous aluminium chloride (15 gms.). A vigorous reaction ensues, and crystals of aluminium double compound separate; the flask is then heated in an oil-bath to 120° for three hours, when methyl chloride is steadily evolved. At the end of this time the aluminium phenolate is decomposed by cold water acidified with hydrochloric acid, and the phenol extracted with ether.

Unchanged anisole is removed from the phenol thus obtained, by dissolving the latter in sodium hydroxide and re-precipitating with acid, and again extracting with ether. Yield, about 5 gms.

Toluene from *p*-Toluidine.

[Ber., 1889, 22, 587.]

p-Toluidine (15 gms.) is dissolved in 45 c.c. conc. hydrochloric acid diluted with 90 c.c. of water, and

diazotised with sodium nitrite (10·5 gms.). The diazonium solution is poured into caustic soda solution made by dissolving 22 gms. of sodium hydroxide in 75 c.c. of water, and the mixture is kept below 10° all the time. This alkaline mixture containing the diazonium salt is next added slowly, through a condenser, to alkaline stannous chloride solution, in a flask which is immersed in ice. The alkaline tin solution is prepared by dissolving tin chloride (45 gms.) in water (110 gms.), and adding 50 per cent. caustic soda solution till the precipitated tin hydroxide almost dissolves. A vigorous evolution of nitrogen takes place after each addition of the diazo-solution and impure toluene separates; this is removed by steam distillation, and the toluene in the distillate separated and dried over calcium chloride. Yield, about 8 gms.

DrepBooks

Diphenyl.

[Ber., 1876, **9**, 467.]

Benzene (100 gms.) is boiled and the vapour passed through an iron or glass combustion tube 1 metre long, which is filled with granulated pumice and heated to redness in a furnace. The vapours issuing from the combustion tube (consisting of diphenyl, unchanged benzene, and hydrogen) are passed through a condenser so arranged as to bring the diphenyl, etc., back to the flask of boiling benzene. A glass tube fused into the lower end of the condenser serves for the escape of hydrogen which is liberated during the reaction. By this

arrangement, the vapours pass repeatedly through the red-hot pumice, and after two hours, the contents of the flask may be distilled and that portion boiling below 150° rejected. The remainder, in the distilling flask, solidifies on cooling and may be recrystallised from alcohol. M.p., 71°.

Oxalic Acid.

[J. Prakt. Chem., 1907, **75**, 146.]

Concentrated nitric acid (140 c.c.) containing vanadium pentoxide (0·1 grm.) is warmed gently in a litre-flask; it is then placed in a fume-cupboard and powdered cane-sugar (20 gms.) is added.

As soon as the reaction becomes vigorous and brown fumes are evolved, the flask is placed in cold water to moderate the reaction. The mixture is allowed to stand for twenty-four hours, by which time the oxalic acid will have crystallised; the crystals are drained and recrystallised from water. Yield, about 16 gms.

APPENDIX VI

PRACTICAL WORK: IRON. NICKEL. PLATINUM

o-Amino-benzaldehyde.

[Ber., 1884, 17, 456, 754.]

o-Nitro-benzaldehyde (10 gms.) is suspended in a litre of water, containing 100 gms. of ferrous sulphate in solution, and excess of ammonia solution is added. The mixture is then heated to 100° for ten minutes and afterwards steam-distilled; the amino-benzaldehyde is extracted from the distillate with ether. M.p. 39°.

DropBooks

o-Amino-cinnamic Acid.

[Ber., 1882, 15, 2299.]

o-Nitro-cinnamic acid (30 gms.) is reduced by ferrous sulphate (270 gms.) as above. Instead of steam-distilling, it is advisable to filter from ferric hydroxide and to precipitate the amino-acid in the cold solution by adding glacial acetic acid. Bright yellow needles of amino-cinnamic acid separate. Yield, 54 per cent. M.p. 158°.

Mannose from Mannitol.

[Trans., 1899, **75**, 9.]

Mannitol (40 gms.) is dissolved in water (100 c.c.), and powdered ferrous sulphate (10 gms.) added. When this has dissolved, the clear solution is oxidised by added "20-volume" hydrogen peroxide (120 c.c.) gradually. After standing for two hours the solution is divided into two parts, one of which is used for isolating the mannose as follows: The solution is treated with excess of barium carbonate and filtered from iron oxide, etc. It is then distilled under diminished pressure at 50° to remove water, and the syrup obtained is then transferred to a dish and allowed to crystallise. Yield of mannose, 8–10 gms.

The second half of the above solution is again divided and one part used for preparing the hydrazone, while the other part serves for preparing the osazone.

The hydrazone is prepared by making the solution alkaline with sodium carbonate and then acidifying with acetic acid; to this solution is added phenyl-hydrazine (5 gms.) which has been dissolved in 25 per cent. acetic acid. After standing for forty-five minutes the hydrazone is filtered off, washed with a very little acetone and recrystallised from water. Pale yellow crystals; m.p. 181°. Yield, about 5 gms.

The portion used for preparing the osazone is made alkaline with sodium carbonate, then acidified with acetic acid, and phenyl-hydrazine (10 gms.) dissolved in 25 per cent. acetic acid is added together with 10

gms. of sodium acetate in a little water. This mixture is digested on the water-bath for three hours, after which the osazone is filtered, washed with water, and recrystallised from alcohol. M.p. 195°; yield, about 8 gms.

Hexahydro-benzene.

[Compt. rend., 1901, **132**, 210.]

A 50 cm. combustion tube is loosely packed with pumice, which has been previously mixed with an equal weight of nickel oxide and a little water, and gently dried.

This is then placed in an air-bath and heated to about 300° while a stream of hydrogen gas is passed through, to reduce the oxide. When no more steam is produced the tube is allowed to cool, and to one end is attached a distilling flask, containing 30 c.c. of benzene, through the neck of which, a glass tube passes connected with a hydrogen-generating apparatus. The hydrogen is allowed to pass through the tube, driving out all air, and is then made to bubble through the benzene warmed to 30°, while the nickel-pumice is heated to 180°–190°. About six hours is required to pass all the benzene through and to convert it into hexahydro-benzene. Any unchanged benzene is removed by nitrating the distillate. Yield, 80 per cent. B.p. 80°–82°.

DropBooks

Hexahydro-phenol.

[Compt. rend., 1901, **132**, 210.]

About 40 gms. of phenol may be reduced by hydrogen in the presence of reduced nickel, by the

same method as hexahydro-benzene is prepared. The temperature of the nickel should be 160°–170° and the phenol may be heated nearly to its boiling point while a fairly rapid current of dry hydrogen bubbles through it. The distillate ultimately obtained, is shaken with caustic soda solution to remove unchanged phenol, extracted with ether, and after drying the extract over potassium carbonate, it is fractionally distilled.

B.p. of hexahydro-phenol is 170°.

INDEX

Accomphthone, 85
Acetic anhydride, 32, 125
Acetoacetic ester, 6, 111
  hydrolysis of, 10
Acetonyl acetone, 12
Acetophenone, 157
Acetosuccinic ester, 113
Acetyl-acetoacetic ester, 11, 117
Acetyl-acetophenone, 123
Acetyl-acetone, 6, 23
Acetyl-pyromuconic ester, 18
Acid anhydride formation, 4, 32, 125
Acid potassium sulphate, 31
Acridine, 71, 149
Acrolein, 31, 128
α-Acroso, 26, 62
Acrylic acid, 128
Adipic acid, 35, 60, 120, 141
Aluminium-mercury couple, 73, 82
Aluminium chloride, 77, 153
  oxide as catalyst, 97, 100
Amino-benzaldehyde, 102
Amino-cinnamic acid, 102
Ammonia, synthesis of, 100
Anisole, 105, 159
Anthranilic acid, 36, 74
Anthraquinone, 159
Antimony, 80
  oxide, 97
Antipyrine, 13, 117

Boilby's cyanide process, 20
Benzal aniline, 32
Benzoic acid, 137
  anhydride, 105
Benzoin condensation, 30, 126
Benzophenone, 77
Benzoyl-acetone, 23
Benzoyl-benzoic acid, 79, 158
Benzyl cyanide, 14
Bismuth oxide as catalyst, 97
Bhuise, 64
Butane tetracarboxylic ester 15

Camphelide, 62, 139
Camphor, 61, 139
Camphoric acid, 20, 61, 139
Camphoronic acid, 66
Carbazole, 37, 151
Carbides, 54
Carbon suboxide, 68
Carbonyl chloride, 109
Castner cyanide process, 23
Chlorbenzoic acid, 134
Chlorobrom-propane, 103
Chloroformic ester, 6, 109
o-Chlortoluene, 134
p-Chlortoluene, 135
Cinnamic aldehyde, 26
  ester, 18
Cinnamyl-vinyl-methyl ketone 125
Citric ester, 66, 144
Claisen, 8, 19
Cobalt as catalyst, 91
Copper as catalyst, 91
Cyanacetic ester, 14
Cyanamide, 55, 142
Cyclo-acetals, 66
Cyclo-butylene, 41

Dioxybenzoin, 14

Desyl-acetophenone, 30, 126
Diaceto-succinic ester, 11, 40, 116
Diacetyl-dicarboxylic ester, 20
Diacetylene dicarboxylic acid, 37
Diazo-compounds, 38
Dibenzoyl methane, 19
Di-isatogen, 38
Di-isopropyl succinic acid, 35
Di-keto-hexamethylene, 17, 119
Diketones by ZnRI, 65
β-Diketones by $AlCl_3$, 79
Dimethyl-aniline-phosphor-chloride, 82, 153
  glutaric ester, 20
  succinic ester, 14, 35
Di-o-nitrophenyl-diacetylene, 38, 132
Dipentene, 31, 52
Diphenyl, 160
  diacetylene, 38
  methane, 154
Di-tertiary glycols, 50

Esterification by catalysts, 98
Ethane tetracarboxylic ester, 11, 116
Ethoxy-quinoline, 73, 151
Ethyl acetophenone, 124
Ethyl benzene, 104
Exhaustive methylation, 41

Fats, hydrolysis by PbO, 85
Ferric chloride, 88
Ferrous sulphate, 88, 162
Fluorescein, 148
Formaldehyde, 100, 135
Friedel-Crafts' reaction, 77, 153
Furfurane, 12
Furfurol acrolein, 25, 124

Gattermann, 39, 135
Glycerose, 26
Grignard reagent, 41, 137
Guanidine, 56, 142

Hexahydrophenol, 164
Hexamethylene, 4, 61, 106, 164
Hexaphenyl ethane, 40
Hydrindone, 79, 155
Hydrogen peroxide, 89, 163
Hydrolysis by $AlCl_3$, 82, 159
  by catalysts, 99
Hydroxymethylene camphor, 22, 122
  ketones, 23

Indigo, 23, 25, 38, 74
p-Iodopropionic acid, 35, 128
Ionone, 28
Isoprene, 24
Isoquinoline, 70, 146

Keten, 68, 101
δ-Keto-hexahydrobenzoic acid, 14, 52
Keto-pentamethylene, 60, 141
  carboxylic ester, 18
Komppa, 20

Lead monoxide, 85
  organo-compounds of, 19, 50, 83, 120
  peroxide, 85, 149
  tetraphenyl, 50, 120

Magnesium syntheses, 45, 137
Malachite green, 31, 71, 148
Malonic ester, 11, 16, 114
Manganese dioxide, 97
Mannose, 162
Mercury diphenyl, 50, 120
Mercuric oxide, 74
p-Menthadiene, 53
Mesityl-oxide-oxalic ester, 18
Metallic oxides as catalysts, 97
Methane, synthesis of, 37
Methyl benzoate, 111
  succinic ester, 118
  indole, 72, 150
Molybdenum, 86

Naphthalene, 146
Naphthyl-phenyl-ketone, 67
Nickel as catalyst, 89, 164
Nitrides, 58
o-Nitro-cinnamic ester, 132
Nitro-compounds, reduction of, 88, 94, 101, 162

DropBooks

Nitrogen fixation, 54
Nitroso-ketones, 22

Olefines from alkyl chlorides, 99
Organo-metals, 19, 50, 52, 82, 120
Oxalic acid, 161
Oxalyl-acetic ester, 21, 121

Palladium, 101
Pentamethylene, 61, 141
Petroleum formation, 91, 96
Phenanthroxylene acetoacetic ester, 32, 127
Phenyl-ethyl-carbinol, 138
Phenyl salicylic acid, 36
Phenyl-tolyl-methane, 67
Phloroglucin, 17
Phthalic acid, 74, 152
Phthalide, 146
Pivalic acid, 50
Platinum as catalyst, 93
Polymethylenes, 4
Potassium alkyl sulphate, 3
cyanide, 30, 126
ferricyanide, 37, 133
hydroxide, 31, 127
nitrate, 32, 125
Propiolic acid, 37
Propyl chloride, 72, 150
Pyrazolon, 14, 118
Pyrrol, 12, 69
Pyruvic acid, 31

Quinoline, 25, 27
Quinones, 27

Reformatsky's reaction, 65, 66, 144
Rubber, artificial, 24

Sabatier and Senderens, 89
Sandmeyer's reaction, 39, 134
Silicon tetraphenyl, 19, 50, 121
Silver cyanide, 40
hydroxide, 41
Sodamide, 22, 124
Sodium cyanide, 23, 57
ethylate, 19, 122
hydroxide, 24, 124
Stannous chloride, 159
Suberic ester, 35
Succino-succinic ester, 16, 119

Teraconic ester, 19
Terpineol, 31
Tetra-acetyl ethane, 13
Tetramethylene carboxylic ester, 15
Thiophene, 12
Thoria as catalyst, 98
Tin tetrachloride, 87
Tin tetraphenyl, 19, 50, 82, 120
Toluene, 159
Toluic aldehyde, 154
Triacetyl-benzene, 20
Trimethyl carbinol, 138
Trimethylene, 4
dicarboxylic acid, 109
Triphenyl benzene, 32
carbinol, 139
methane, 156
methyl, 40
Tungstic oxide as catalyst, 98

Vanadium pentoxide, 87, 161

Wurtz-Fittig reaction, 2, 104

Zinc alkyl syntheses, 64, 145
as a reducing agent, 69, 146
chloride, 70, 148

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